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PROGRESS REPORT
ENVIRONMENTAL PROGRAMS
—1978—

WHITE RIVER SHALE PROJECT
Federal Prototype Oil Shale Leases
Ua and Ub

July 1979

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.U82
W417
1978

WHITE RIVER SHALE PROJECT
1315 WEST HIGHWAY 40
VERNAL, UTAH 84078
(801) 789-0571

July 17, 1979

Mr. Henry O. Ash
Executive Director
Oil Shale Environmental Advisory Panel
U. S. Department of Interior
Office of the Secretary
Denver Federal Center, Rm. 820-A, Bldg. 67
Denver, Colorado 80225

Re: "Progress Report -- 1978 Environmental Programs"

Dear Mr. Ash:

We have sent to you today under separate cover thirty (30) copies of the subject report. The report discusses the results of the environmental programs for the 1978 calendar year, and water year (October 1, 1977 - September 30, 1978).

The hydrological, biological and air resources monitoring programs conducted during 1978 are continuing through 1979. The revegetation research program initiated in 1974 was completed December 31, 1978, although certain studies are continuing through 1979.

Please contact me if you have any questions concerning our work to date or our plans for the future.

Sincerely,

Rees C. Madsen
Manager

RCM/nh

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United States Department of the Interior

GEOLOGICAL SURVEY

Conservation Division
Area Oil Shale Supervisor's Office
131 N. 6th, Suite 300
Grand Junction, Colorado 81501

July 20, 1979

Memorandum

To: Hank Ash, Chairman OSEAP

From: Peter A. Rutledge, Area Oil Shale Supervisor

Subject: WRSP Progress Report -- 1978 Environmental Programs

Enclosed for your information and panel use are thirty (30) copies of White River Shale Project's Progress Report -- 1978 Environmental Programs. The report discusses the results of the environmental programs for the 1978 calendar year and water year (October 1, 1977 - September 30, 1978).

Peter A. Rutledge

Enclosures

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PROGRESS REPORT

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WHITE RIVER SHALE PROJECT

FEDERAL PROTOTYPE OIL SHALE LEASES U-a AND U-b

July 1979

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Section 1.0

SUMMARY

This "Progress Report -- Environmental Programs" addresses the work accomplished during the period January 1, 1978 - December 31, 1978. The water resources work, however, is reported on a water year basis. The water year discussed in this report is the period October 1, 1977 - September 30, 1978. During these periods the White River Shale Project continued collecting data on water, air and biological resources on and near the Federal Oil Shale Prototype Program Lease Tracts Ua and Ub in northeastern Utah.

1978 was a relatively dry year on Tracts Ua and Ub. Average precipitation over the water year (October 1977 - September 1978) totaled around 7 inches, only about 65% of normal. Evaporation over the period May 1978 - September 1978 was around 32 inches of water.

Flow in the White River was higher than in the preceeding year. The high flow recorded was around 3900 cubic-feet-per-second, and low flow around 100 cubic-feet-per-second. Total water year water flow was 532,000 acre-feet.

Dissolved and suspended solids levels in the White River measured during the 1978 water year were fairly typical of those measured during preceeding years. Dissolved solids concentrations ranged from 267 milligrams-per-liter to 661 milligrams-per-liter. Over 1.4 million tons of suspended solids (sediment) passed the monitoring sites during the twelve month water year.

Air resources monitoring continued through 1978. One station was operated for the collection of air quality data. Four stations were operated for the collection of meteorological data.

Air quality remained relatively good on the tracts during 1978. Only ozone, non-methane hydrocarbons and particulates were present in measurable quantities. Equipment measuring carbon monoxide, sulfur dioxide and nitrogen oxide routinely recorded numbers at the threshold of the equipment detection capability.

The peak hourly average ozone concentration was 137 micrograms-per-cubic-meter during 1978. The new Federal National Ambient Air Quality Standard is 240 micrograms-per-cubic-meter. The average one-hour measurements ranged from 58 micrograms-per-cubic-meter during the Fall to 78 micrograms-per-cubic-meter during the Spring.

Suspended particulate concentrations during 1978 showed an annual geometric mean of 15 micrograms-per-cubic-meter. This is less than the most restrictive existing Federal Standard of 60 micrograms-per-cubic-meter. The highest 24-hour average concentration recorded was 63 micrograms-per-cubic-meter. The most restrictive 24-hour standard is 150 micrograms-per-cubic-meter.

Monitoring of vegetation productivity, sagebrush stem growth, and general vegetation conditions continued through 1978. Weather was more favorable to plant growth during 1978 than during 1977. Plant productivity was generally consistent, however, with that of previous years. Stem growth of sagebrush was better than average. The use of stem growth as an indicator of environmental fluctuations continued to be investigated but was not confirmed during 1978.

Terrestrial vertebrate monitoring also continued during 1978. Monitoring of terrestrial vertebrates on Tracts Ua and Ub provided some interesting data concerning their populations in 1978. Bird populations remained at low abundance. Some species like the Brewer's and chipping sparrows reached their lowest abundance in 1978 since monitoring started in 1974. Chipping sparrow's total abundance in 1975 in all habitats was close to 3.0/km. In 1978 their abundance was 0.03/km. Brewer's sparrow's total abundance was nearly 12/km in 1975. In 1978 their abundance was less than 1.0/km. Two new bird species occurred on the tracts - the merlin or pigeon hawk was observed along the White River in August; and a long-billed marsh wren was captured while mist-netting bats at a pond in Asphalt Wash.

Among the mammals, cottontail rabbit populations declined in 1978 to a low abundance similar to 1975 in three vegetation communities. Rabbit abundance increased in sagebrush-greasewood community in Southam Canyon. One new mammal species was observed on the tracts -- the gray fox. Rodent densities increased slightly from their four-year low which occurred in 1977. Bat populations increased dramatically - a total of 263 were captured in June and August at a pond in Asphalt Wash. Swallows and nighthawks, two other groups of invertebrate consumers, also reached high abundance in 1978.

Among the reptiles, snake observations remained low. There were some changes in abundance among specific lizard species; however, as a group, their abundance remained stable as it has since 1975. Amphibian observations were few and far between in 1978.

It now appears after four years of monitoring that three classes of terrestrial vertebrates provide the following view of the tracts. Birds

are the first clue to annual fluctuations in the environment including changes in precipitation, seed production and invertebrate production. Mammals, specifically the rabbits and rodents, respond a year after the birds have been affected. The lizards have yet to be affected by environmental change which has significantly influenced the birds and the mammals.

Work on the revegetation of disturbed sites and processed shale was completed during 1978. A final report was issued in early 1979. The work showed that disturbed sites could be reclaimed and that plant materials could be grown in processed shale.

Work plans for environmental work during 1979 are similar to those in 1978. The results of the five years of effort are going to be rigorously reviewed at the end of 1979. It is expected that the level of effort can be reduced for 1980 unless development of Ua and Ub is able to be reinitiated soon.

Section 2.0

INTRODUCTION

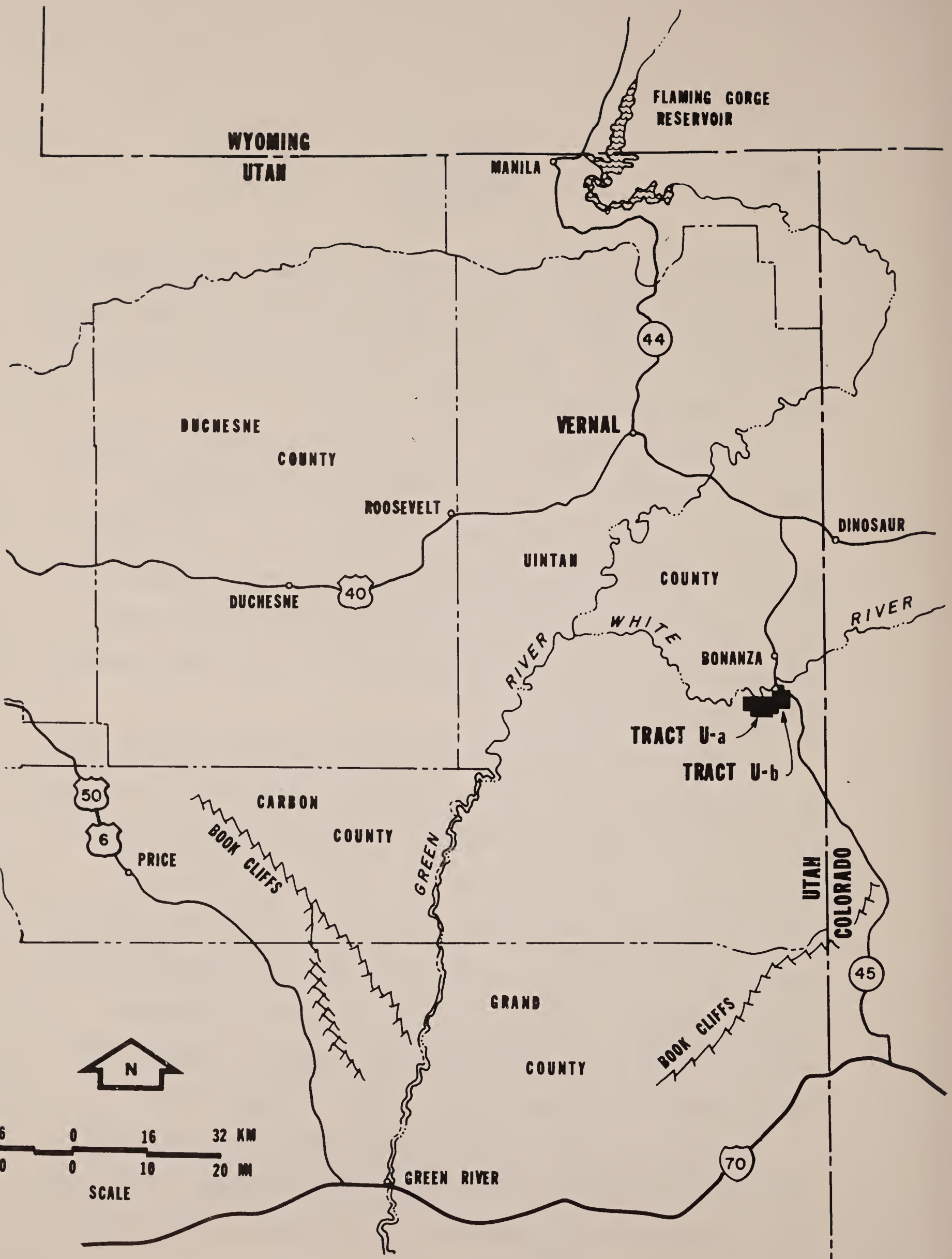
The White River Shale Project (WRSP) was formed in 1974 to carry out the joint development of the two Federal Prototype Oil Shale Leasing Program tracts in Utah. These tracts are called Ua and Ub. Figure 2-1 shows the location of these two 5,120 acre areas.

Ua and Ub are located about fifty road miles southeast of Vernal, Utah. The White River flows just to the north of the properties.

WRSP is responsible to Phillips Petroleum Company, Sohio Natural Resources Company, and Sunoco Energy Development Company (Sunedco) for making and implementing plans for the development of the oil shale resource of Tracts Ua and Ub. Sunedco and Phillips hold the lease to Ua. Sohio holds the Ub lease.

Two significant tasks have been completed by WRSP since work under the leases began in 1974. First, the Detailed Development Plan required by the leases was submitted to the U. S. Geological Survey -- Area Oil Shale Supervisor (AOSS) in June of 1976. This plan describes the schedule, activities and expected results associated with the planning, construction and operation of a commercial shale oil production facility on Tracts Ua and Ub. Second, the required two year environmental monitoring and data collection program was completed in January 1977. The final report on this work was published in October of 1977.

Operations under the Ua and Ub leases, however, were suspended by the Department of Interior for one year starting November 1, 1976. This action postponed the implementation of the program described in the



PROJECT LOCATION MAP
TRACTS U-a & U-b

FIGURE 2-1

Detailed Development Plan. The lease terms were suspended because environmental monitoring work had shown the presence of high levels of ozone and non-methane hydrocarbon gases in the air around the Ua and Ub tracts.

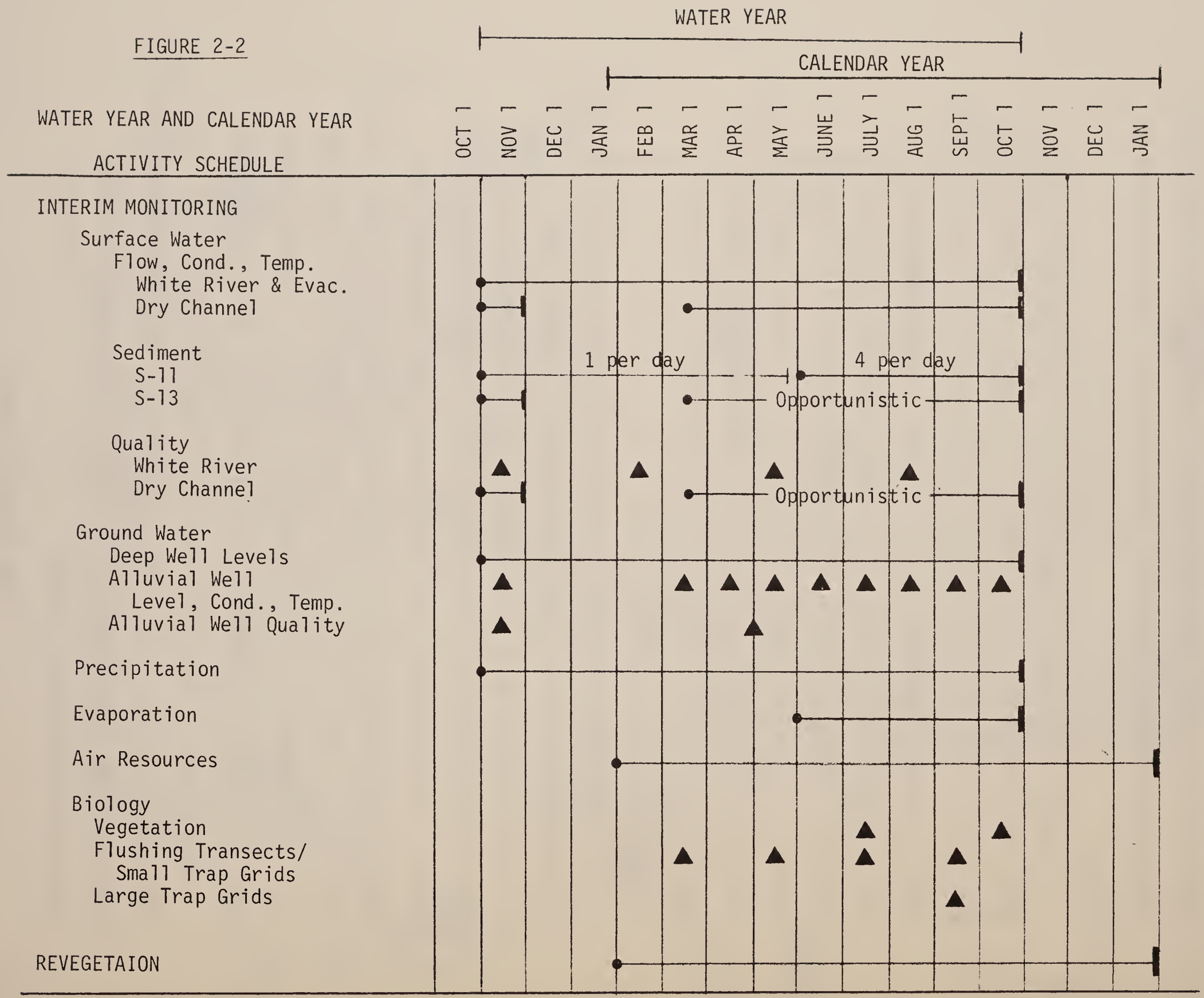
A second suspension of lease terms became effective May 31, 1977 which was prior to the first Department of Interior's initiated suspension period expiring. This second suspension was by court order issued against the Department of Interior in favor of the WRSP participants. The basis for this court action was several questions affecting the current and eventual validity of the Federal leases held by the WRSP companies. These questions came about as a result of 1977 court decisions involving unpatented mining claims, and litigation concerning a company's filing for a Utah state lease on the area covered by the Federal leases to Ua and Ub.

The court order suspending the terms, obligations and conditions of the Ua and Ub Federal lease terms was in effect during 1978.

WRSP, however, decided to continue collecting data concerning air, water and biological resources around Ua/Ub. The basic reasons for this decision were a desire to confirm some observations made during the baseline study period, track the ozone and non-methane hydrocarbon levels over a longer period, evaluate more refined biological resources monitoring techniques, and to complete a revegetation research program. The scope of activities carried out during 1978 are shown in Figure 2-2.

The purpose of this "Annual Report -- Environmental Programs" is to report on the results of the 1978 activities that were related to the WRSP environmental monitoring, data collection and research efforts associated with Tracts Ua and Ub.

FIGURE 2-2


WATER YEAR AND CALENDAR YEAR
ACTIVITY SCHEDULE
WATER YEAR
CALENDAR YEAR
OCT 1
NOV 1
DEC 1
JAN 1
FEB 1
MAR 1
APR 1
MAY 1
JUNE 1
JULY 1
AUG 1
SEPT 1
OCT 1
NOV 1
DEC 1
JAN 1
INTERIM MONITORING
Surface Water
Flow, Cond., Temp.
White River & Evac.
Dry Channel
Sediment
S-11
S-13
1 per day
4 per day
Opportunistic
Quality
White River
Dry Channel
Opportunistic
Ground Water
Deep Well Levels
Alluvial Well
Level, Cond., Temp.
Alluvial Well Quality
Precipitation
Evaporation
Air Resources
Biology
Vegetation
Flushing Transects/
Small Trap Grids
Large Trap Grids
REVEGETAION
LEGEND:
● = start
| = stop
▲ = distinct task performance

Section 3.0

BASELINE ENVIRONMENTAL MONITORING PROGRAM

The field work for the required two-year Environmental Baseline Monitoring and Data Collection Program was completed in its entirety January 15, 1977. The "Final Environmental Baseline Report" was published in October of 1977.

The baseline period is the reference point for discussion of the results of work done in later years. The baseline period was generally the years 1975 and 1976. The reference for the water work, however, is the October 1, 1974 - September 30, 1975 and October 1, 1975 - September 30, 1976 "water" years.

Section 4.0

ENVIRONMENTAL MONITORING PROGRAM

The purpose of this section is to discuss the work carried out during 1978 regarding the water, air and biological resources of Tracts Ua and Ub. This work was done as part of the environmental monitoring program that has operated continuously since 1974.

The majority of the environmental monitoring work necessary for use in satisfying the requirements of the lease, acquiring permits, and providing a base for evaluating the effects of oil shale development activities was completed during the two-year Environmental Baseline Monitoring and Data Collection Program. Consequently, the environmental monitoring work since January 1977 has been done for essentially three reasons: (1) to maintain the applicability of the baseline results to future periods of time, (2) to track airborne ozone and non-methane hydrocarbons concentration levels, and (3) to evaluate techniques for separating natural fluctuations in the parameters that affect the biological system from man-made effects.

The program carried out since the completion of the Baseline study period is called the "Interim" monitoring program. This is because it was expected to be carried out during all or part of the time between the completion of the Baseline study period and commencement of the monitoring activities that will be carried out during development work on Ua and Ub.

The remainder of this section discusses the work done during the period October 1, 1977 - September 30, 1978 for water resources, and January 1, 1978 - December 31, 1978 for air and biological resources.

4.1 WATER RESOURCES

The two year water resources Environmental Baseline Monitoring Program was completed in total in January 1977. An Interim Monitoring Program was implemented after completion of the Baseline Program. This section of the Progress Report will discuss the water resources monitoring work performed during the period October 1, 1977 through September 30, 1978.

The United States Geological Survey (USGS) has been conducting a water resources data collection program in the Uintah Basin. Much of this data collection has been taking place in the immediate vicinity of Tracts Ua/Ub. The WRSP Water Resources Monitoring Program was designed to be used in conjunction with pertinent portions of the USGS program. The two data collection programs combined adequately monitor streamflow, suspended sediment, and water quality at locations on the White River, Evacuation Creek, and at the mouth of Southam Canyon. Also, streamflow is monitored at the mouths of Hell's Hole Canyon and Asphalt Wash.

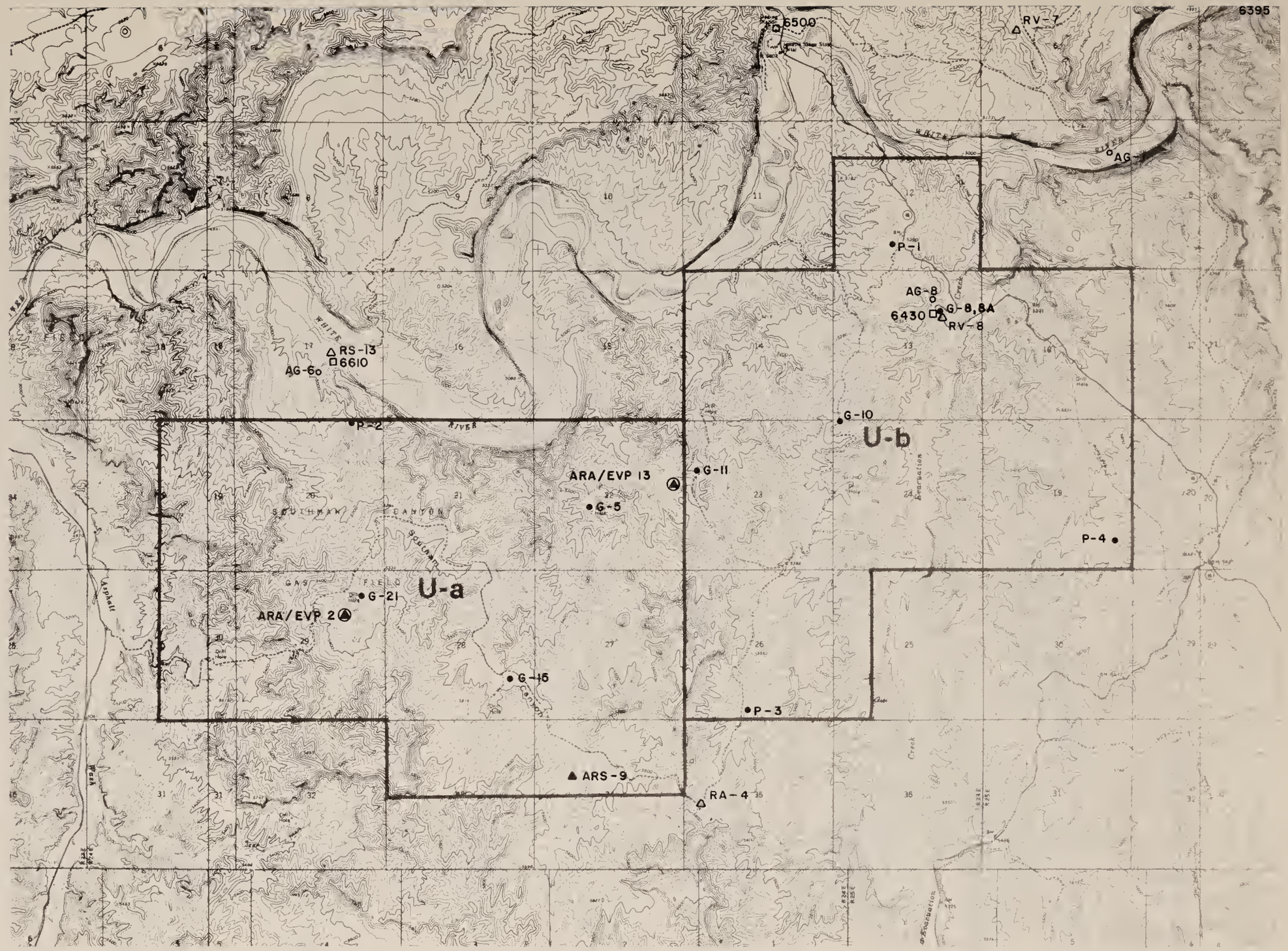
The Bird's Nest and Upper aquifers are continuously monitored for water level fluctuations. Additional semiannual water level measurements are being taken for area correlation.

Alluvial aquifers are monitored for water levels and water quality at locations upstream and downstream of the tracts on the White River and on Evacuation Creek, and at locations at the mouths of Southam Canyon, Hell's Hole Canyon, and Asphalt Wash.

Precipitation and evaporation are monitored at the proposed plant site, in Southam Canyon, and the surrounding area.

Figure 4-1 shows the locations of sites for the four types of monitoring being conducted -- surface water, deep aquifer water, alluvial water, and precipitation/evaporation monitoring. All support-

WATER RESOURCES MONITORING SITES



6700 □ ○AG-3

LEGEND

- □ SURFACE WATER
- • DEEP AQUIFER WATER
- ○ ALLUVIAL WATER
- ▲ PRECIPITATION (AUTOMATIC)
- △ PRECIPITATION (STORAGE)
- ◬ PRECIPITATION (AUTO.)/EVAPORATION PAN

1 0 1
SCALE IN MILES

VTN

FIGURE 4-1

ing data are shown in the figures and tables of the text and in the field data section. All USGS data in this report are preliminary and subject to revision.

VTN Inc. is under contract to WRSP to conduct the water resources monitoring program.

4.1.1 Surface Water

The surface water monitoring program comprised work efforts of both the USGS Water Resources Division and WRSP. The division of responsibilities is shown in Table 4-1. In the past more than one system of nomenclature has been used for surface water stations. This report will use only the USGS system of nomenclature for station numbers and names. A comparison of nomenclature for surface water stations is shown in Table 4-2. Also, only the last four digits of the USGS station numbers will be used in the text.

4.1.1.1 Objectives. The objectives of the surface water monitoring program are to ensure the applicability of the two-year Baseline data to future monitoring periods.

4.1.1.2 Methods. Data collection efforts during the reporting period were concerned with streamflow, suspended sediment, and water quality data.

Streamflow was measured continuously by the WRSP on the White River downstream from the tracts (station 6700). The gaging station visitation and maintenance program were sufficient to ensure as near continuous streamflow measurement throughout the lease suspension period as practical. Discharge measurements were made with a current meter as frequently as called for by good hydrological practices, but

TABLE 4-1

RESPONSIBILITY FOR SURFACE WATER MONITORING

Activity	Responsibility
Streamflow	
6700: continuous monitoring	WRSP
6610: continuous monitoring during snowmelt and thunderstorm seasons (approximately February through October)	WRSP
6395, 6430, 6500: continuous monitoring	USGS
6405, 6625: continuous monitoring during snowmelt and thunderstorm seasons (approximately February thorugh October)	USGS
Suspended Sediment	
6700: continuous monitoring (4 samples daily during peak flow and thunderstorm season, 1 sample daily during winter baseflow)	WRSP
6610: opportunistic samples	WRSP
6395: continuous monitoring	USGS
6430: periodic and opportunistic samples	USGS
Water Quality	
6700: quarterly samples in October, January, April, and July; continuous monitoring of temperature and specific conductance	WRSP
6610: opportunistic samples; continuous monitoring of temperature and specific conductance during snowmelt and thunderstorm seasons	WRSP
6395, 6430, 6500: quarterly samples in October, January, April, and July; continuous monitoring of temperature and specific conductance	USGS

TABLE 4-2

COMPARISON OF NOMENCLATURE FOR
SURFACE WATER STATIONS

Designation 1	Designation 2 (USGS)	Name (USGS)
	09306395	White River Near Colorado State Line, Utah
S-5	09306405	Hell's Hole Canyon at Mouth, Near Watson, Utah
	09306410	Evacuation Creek Above Missouri Creek, Near Watson, Utah
S-2	09306430	Evacuation Creek Near Mouth, Near Watson, Utah
S-3	09306500	White River Near Watson, Utah
S-13	09306610	Southam Canyon Wash at Mouth, Near Watson, Utah
S-12	09306625	Asphalt Wash at Mouth, Near Watson, Utah
S-11	09306700	White River Below Asphalt Wash, Near Watson, Utah

no less frequently than once per month. The digital recorder tapes were removed and processed monthly.

Streamflow was also measured by WRSP in lower Southam Canyon (station 6610). According to plan, this station was in operation from October 1, 1977 through November 29, 1977 and March 16, 1978 through September 30, 1978. The station was visited during the period of operation at least once each month. The digital recorder tapes were removed and processed once a month.

Streamflow was monitored continuously by the USGS at station 6395 on the White River below the Colorado State line at station 6500 on the White River near Watson, and at station 6430 on Evacuation Creek near the mouth. Stations 6625 on Asphalt Wash near the mouth and 6405 in Hell's Hole Canyon near the mouth were in operation throughout the year.

Suspended sediment was measured by the WRSP at station 6700. The automatic suspended sediment sampler at this station was to be operated continuously according to the Work Plan. Severe icing conditions and equipment failure, however, required that it be shut down from December 6, 1977 through March 12, 1978 and June 17, 1978 through September 30, 1978. During the shutdown, manual samples were withdrawn at least once every two weeks. Manual suspended sediment samples were collected at intervals necessary to ensure calibration of the automatic sampler, but at least every two weeks through the year. Suspended sediment samples were analyzed by WRSP.

No suspended sediment samples were collected at station 6610. A single-stage sampler and a crest gage were maintained at that location to enhance the chances for data collection.

An automatic sediment sampler was used by the USGS at station

6395. Manual suspended sediment samples were collected by the USGS at station 6430.

Water quality samples were collected at station 6700 in October, January, April, and July by WRSP. No water quality samples were collected at station 6610. Dissolved oxygen, temperature, pH and specific conductance were measured in the field at the time samples were collected.

Temperature and specific conductance were measured continuously at station 6700. Both probes were checked and calibrated regularly and the digital recorder tapes were pulled and processed monthly . Temperature and specific conductance recorders and probes were maintained at station 6610 during the period of its operation.

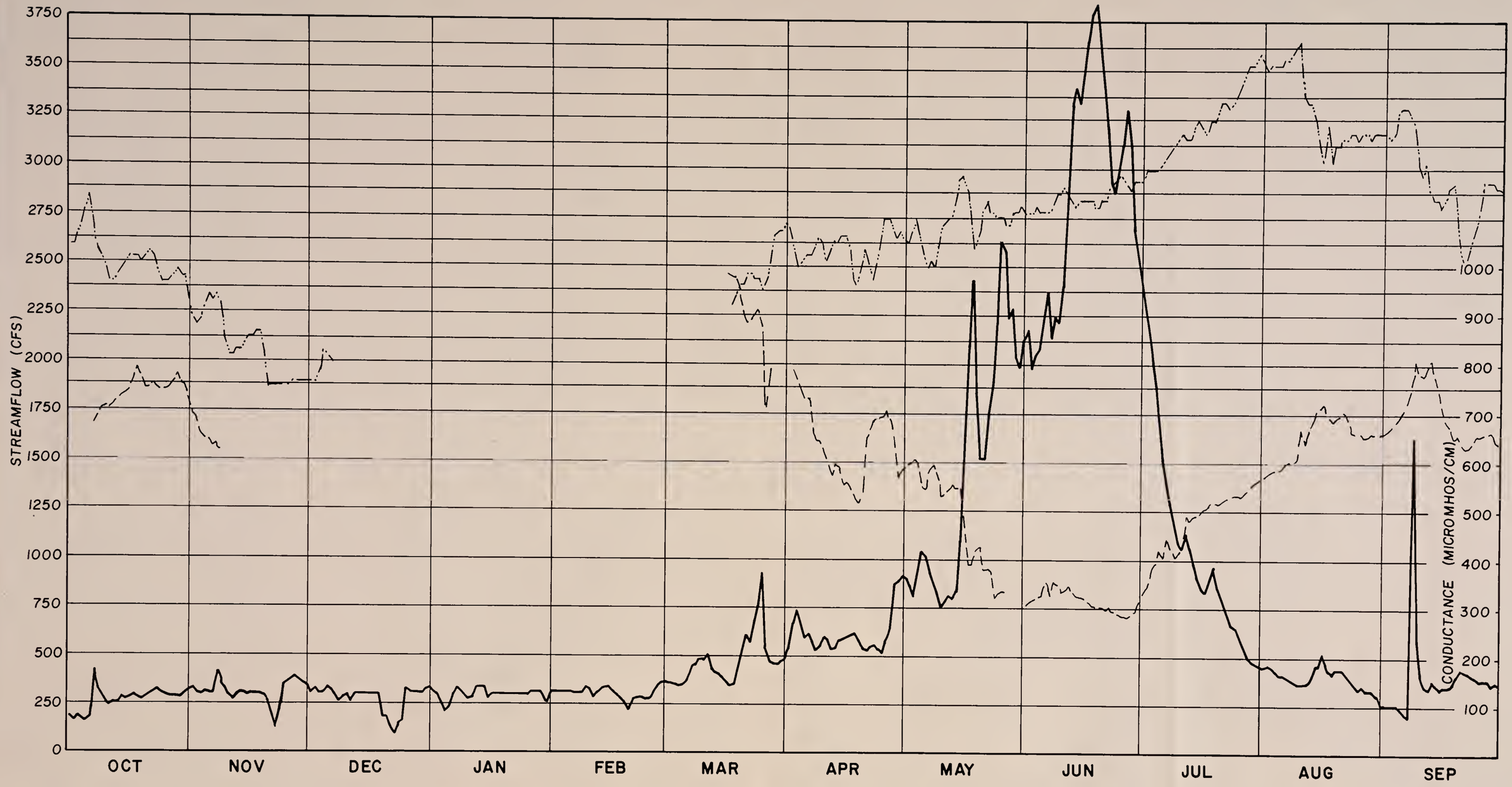
Water quality samples were collected by the USGS in October, January, April, July, and September at stations 6395, 6430, and 6500. Temperature and specific conductance were monitored continuously at stations 6395 and 6500. Temperature was monitored continuously at station 6430.

4.1.1.3 Results to Date.

Streamflow: White River

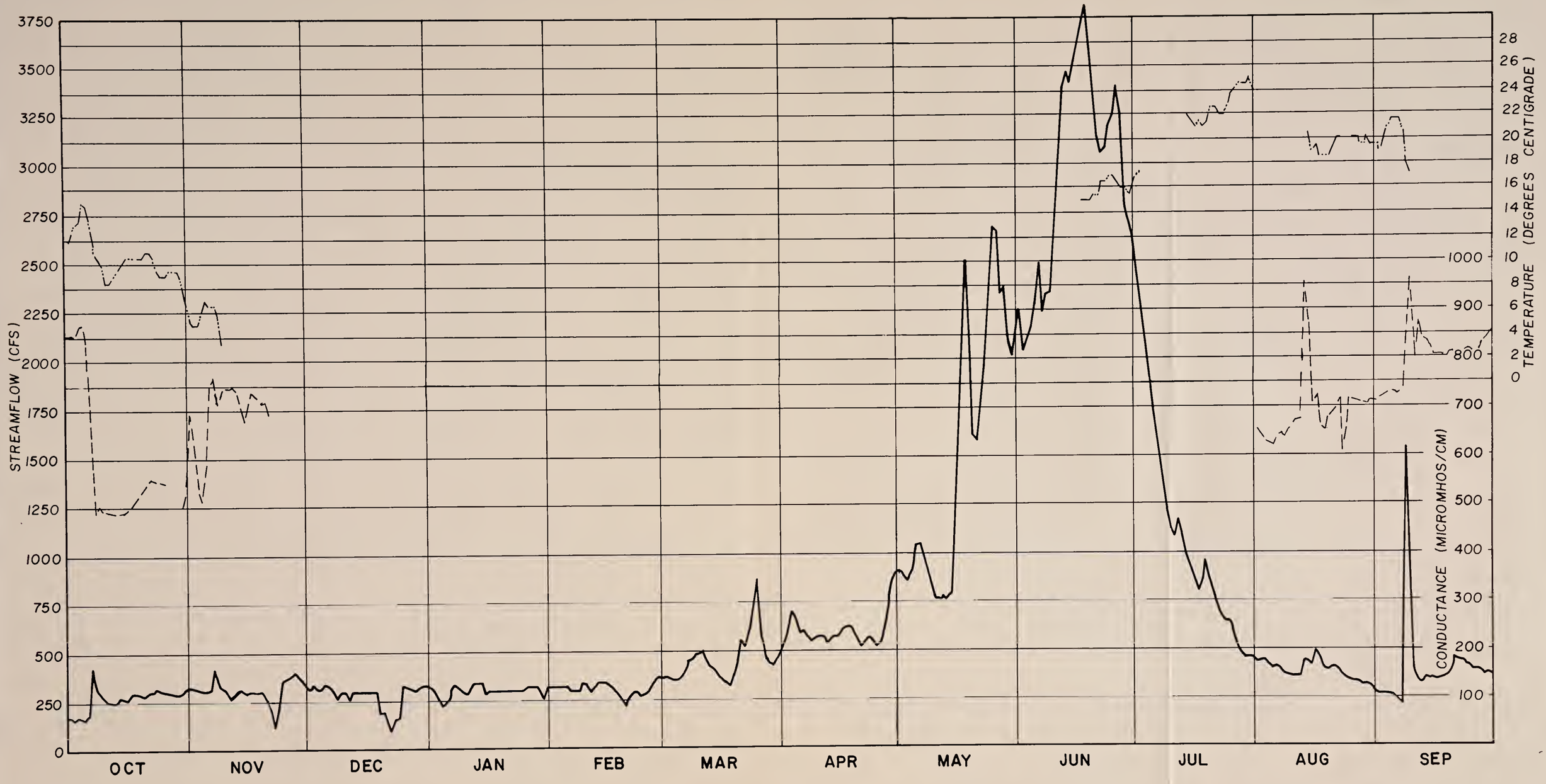
The streamflow, temperature and specific conductance at stations 6395, 6500, and 6700 on the White River are shown in Figures 4-2 through 4-4 . The streamflow regime during the 1978 water year was similar to the regime during the Baseline period. Baseflow occurred from October through February and resumed in late July. Runoff from snowmelt in the lower basin began in early March and lasted through April. Runoff from the snowmelt in the upper basin lasted from May until late July.

Maximum mean daily streamflow was 109 m^3/sec (3860 cfs) at station 6700, and minimum mean daily streamflow was 2.72 m^3/sec (96



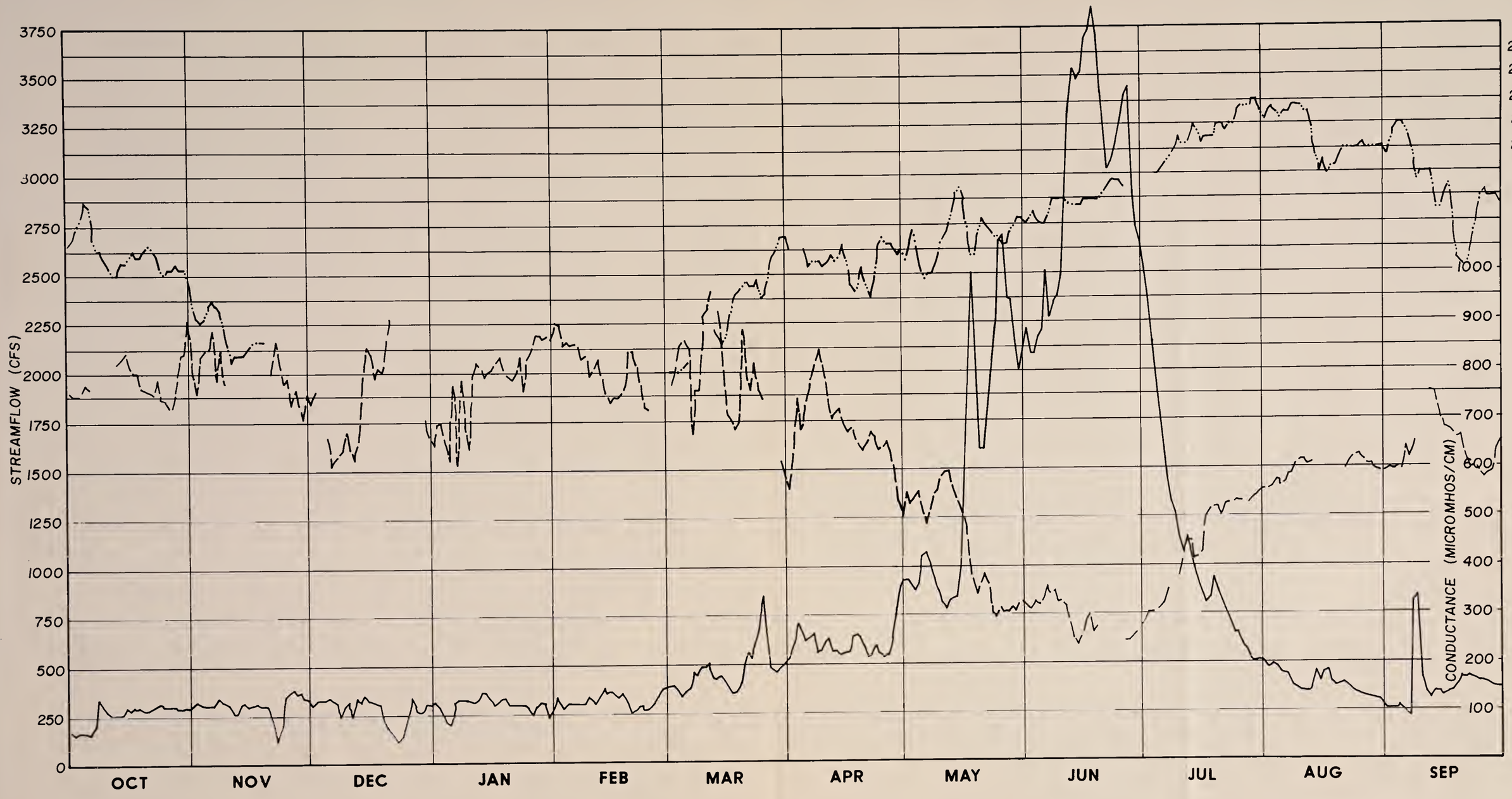
MEAN DAILY STREAMFLOW, TEMPERATURE AND SPECIFIC CONDUCTANCE
WHITE RIVER NEAR COLORADO STATE LINE (09306395)
OCTOBER 1977 - SEPTEMBER 1978

FIGURE 4-2



MEAN DAILY STREAMFLOW, TEMPERATURE AND SPECIFIC CONDUCTANCE
WHITE RIVER NEAR WATSON (09306500)
OCTOBER 1977 - SEPTEMBER 1978

FIGURE 4-3



MEAN DAILY STREAMFLOW, TEMPERATURE AND SPECIFIC CONDUCTANCE

WHITE RIVER BELOW ASPHALT WASH (09306700)

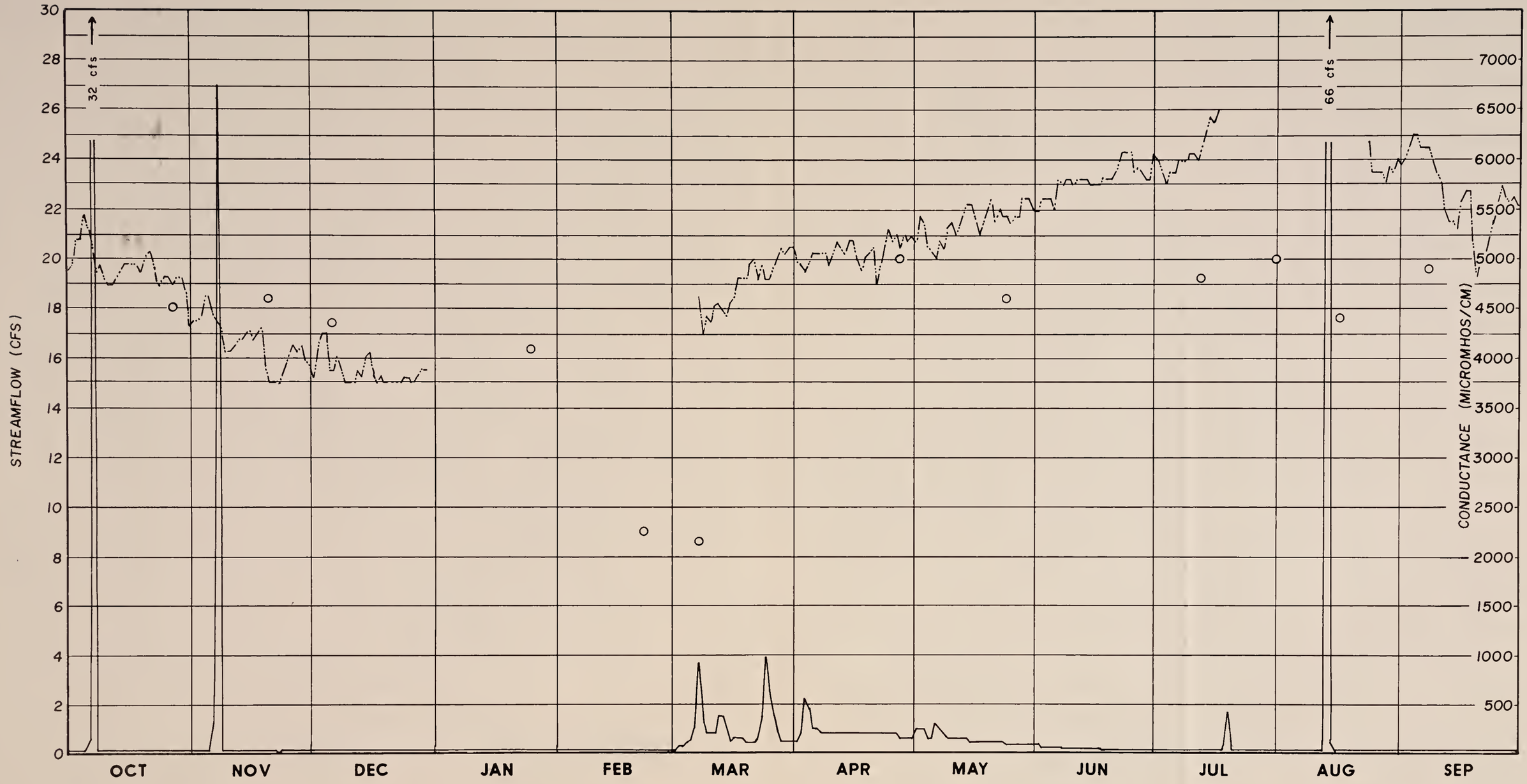
OCTOBER 1977 – SEPTEMBER 1978

FIGURE 4-4

cfs) at station 6500. At station 6700, the maximum instantaneous streamflow was 112 m^3/sec (3950 cfs) on June 18, 1978, and the minimum instantaneous streamflow was 3.00 m^3/sec (106 cfs) on November 22, 1977. A flash flood occurred on September 8 and 9, 1978. The maximum instantaneous streamflow at station 6700 for this flow event was 91.7 m^3/sec (3240 cfs) on September 8th. The total annual runoff for these three stations averaged 65,700 hectare-meter (532,300 acre-feet). There was an increase of 1.1% in total annual runoff from the upstream station (station 6395) to the downstream station (station 6700).

Streamflow: Evacuation Creek

Streamflow, temperature and specific conductance at station 6430 near the mouth of Evacuation Creek are shown in Figure 4-5. This figure illustrates that the streamflow was sustained by baseflow, except for several days of snowmelt runoff during March and brief periods of thunderstorm runoff. The maximum mean daily steamflow was 1.87 m^3/sec (66 cfs) on August 13, 1978, and the minimum mean daily streamflow occurred on November 22, 1977 when there was no flow. The maximum instantaneous streamflow was estimated at 36.8 m^3/sec (1,300 cfs) on August 13, 1978. This estimate was made using a four-section slope-area method. The total annual runoff was 53.9 hectare-meter (437 acre-feet). Although the flow pattern during the 1978 water year was similar to the Baseline period, the total annual runoff in 1978 was 53% less than in 1975 and 61% less than in 1976. This may be attributed mostly to below normal precipitation during the spring of 1978 in the drainage area upstream of this station.



MEAN DAILY STREAMFLOW, TEMPERATURE AND SPECIFIC CONDUCTANCE

EVACUATION CREEK NEAR MOUTH, NEAR WATSON (09306430)

OCTOBER 1977 - SEPTEMBER 1978

FIGURE 4-5

Streamflow: Dry Washes

The mean daily steamflow values for the stations in Southam Canyon, Hell's Hole Canyon, and Asphalt Wash are shown in Table 4-3. A flow event occurred on October 6 and 7, 1977 at all three sations. However, only the station in Hell's Hole Canyon recorded a flow event on November 6 and 7, 1977. Both flow events were due to thunderstorm runoff. The variation of unit runoff between the three stations for the October 6th and 7th flow event indicates that the thunderstorm precipitation causing the runoff was much more intense over the drainage area of Hell's Hole Canyon than over the other two drainage areas. The drainage areas above stations 6610, 6405, and 6625 are 23 km^2 (9 sq mi), 63 km^2 (24.5 sq mi), and 253 km^2 (97.5 sq mi), respectively. The maximum instantaneous streamflow at station 6610 on October 6, 1977 was estimated to have been 0.12 m^3/sec (4.2 cfs). The total 1978 annual runoff at stations 6610, 6405, and 6625 was 0.017 hectare-meter (0.14 acre-feet), 4.56 hectare-meter (37 acre-feet), and 0.23 hectare-meter (1.96 acre-feet), respectively. In comparison to the Baseline period, both the number of flow events during the year and the total 1978 annual runoff were considerably less.

TABLE 4-3

MEAN DAILY STREAMFLOW
DRY WASHES
OCTOBER 1977 - SEPTEMBER 1978

Station	Date	Mean Daily Streamflow	Unit Runoff
Southam Canyon at mouth (Station 6610)			
	10/6/77	0.002 m^3/sec (0.07 cfs)	0.00073 cm (0.00029 in.)
Hell's Hole Canyon at mouth (Station 6405)			
	10/6/77	0.311 m^3/sec (11 cfs)	0.0424 cm (0.0167 in.)
	11/6/77	2.15 m^3/sec (7.6 cfs)	0.0293 cm (0.0115 in.)
	11/7/77	0.006 m^3/sec (0.22 cfs)	0.00085 cm (0.00033 in.)
Asphalt Wash near mouth (Station 6625)			
	10/6/77	0.019 m^3/sec (0.68 cfs)	0.00066 cm (0.00026 in.)
	10/7/77	0.007 m^3/sec (0.26 cfs)	0.00025 cm (0.00010 in.)

Water Quality: White River

The combined water quality data from the three stations on the White River (6395, 6500, and 6700) are summarized in Table 4-4. The data has been grouped according to the source of the streamflow; i.e., baseflow, runoff from the lower basin (below Meeker, Colorado), and runoff from the upper basin (above Meeker). It was determined during the Baseline study that each of these three flow periods has distinct water quality characteristics. In addition, the water quality parameters have been grouped according to general catagories.

General Characteristics: The variation in time of some of the general characteristics is shown in Figure 4-6. Concentration levels of dissolved solids followed an inverse relationship to streamflow, and ranged from 267 mg/l during upper basin runoff to 661 mg/l during baseflow. Levels of pH were stable throughout the year with values from 7.8 to 8.6. Alkalinity and hardness followed an inverse relationship to streamflow.

The relationship of mean daily streamflow, temperature and specific conductance for the three stations on the White River is shown in Figures 4-2 through 4-4. Temperature followed an annual sinusoidal pattern, and specific conductance followed an inverse relationship to streamflow. Specific conductance is an indicator of the concentration of dissolved solids.

The records of suspended sediment discharge during the 1978 water year for stations 6395 and 6700 are shown in Tables 4-5 and 4-6, respectively. The record for station 6395 was prepared by the USGS, and the record for station 6700 was prepared by WRSP. The missing days of record were estimated for station 6395, but not for station 6700. The total annual suspended sediment load for the year at station 6395

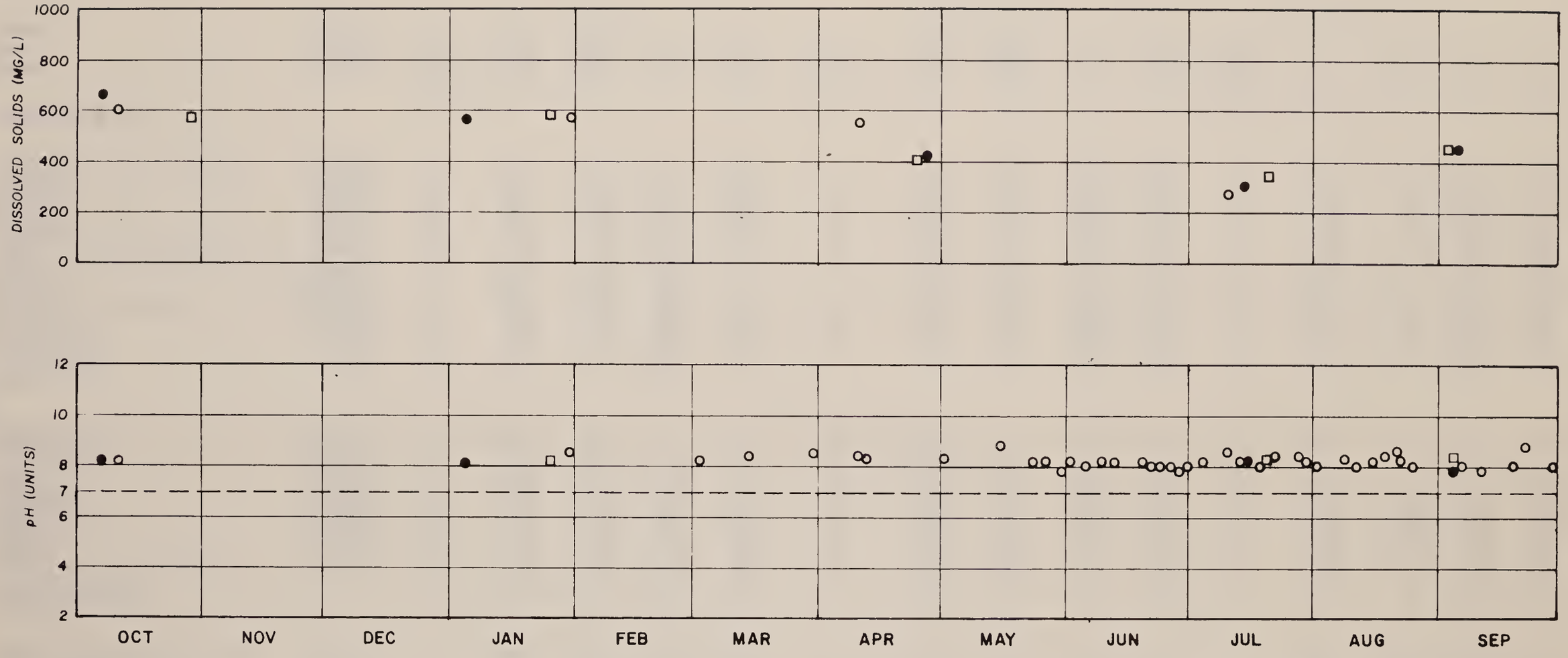
TABLE 4-4

SUMMARY OF WHITE RIVER WATER QUALITY
OCTOBER 1977 - SEPTEMBER 1978

		BASEFLOW					LOWER BASIN RUNOFF					UPPER BASIN RUNOFF				
		No. of Samples	Mean	Stan. Dev.	Max	Min	No. of Samples	Mean	Stan. Dev.	Max	Min	No. of Samples	Mean	Stan. Dev.	Max	Min
GENERAL CHARACTERISTICS																
Total Alkalinity as $CaCO_3$	(mg/l)	8	190	20	210	160	3	170	17	190	160	3	140	20	160	120
Dissolved Solids, Residue at 180 C	(mg/l)	8	551	62	650	461	3	467	75	554	420	3	304	30	337	279
Dissolved Solids, Calc. Sum	(mg/l)	8	555	71	661	449	3	458	80	550	405	3	304	37	340	267
Total Hardness as $CaCO_3$	(mg/l)	8	309	30	360	270	3	270	35	310	250	3	207	23	220	180
Noncarbonate Hardness as $CaCO_3$	(mg/l)	8	118	20	150	94	3	99	18	120	88	3	69	7	76	62
pH	(units)	7	8.20	0.22	8.4	7.8	1	8.4	0	8.4	8.4	3	8.37	0.21	8.6	8.2
Specific Conductance	(umhos/cm)	8	764	126	995	575	3	740	53	800	700	3	473	86	550	380
Streamflow	(cfs)	8	276	51	330	166	3	557	31	582	522	3	986	140	1099	830
Temperature	(^{o}C)	8	10.4	9.2	23.5	0.5	3	12.4	2.4	14.5	9.8	3	20.5	1.4	22.0	19.4
Turbidity	(JTU)	8	280	695	2000	15	3	190	96	300	120	3	67	43	110	25
Color	(PCU)	8	8	7	25	4	3	7	1	8	6	3	9	1	10	8
MAJOR CATIONS																
Calcium	(mg/l)	8	74	7	84	64	3	69	5	75	66	3	56	6	60	49
Magnesium	(mg/l)	8	29	5	40	25	3	24	5	29	21	3	17	2	18	15
Potassium	(mg/l)	8	2.3	0.6	3.7	1.9	3	2.2	0.6	2.9	1.8	3	1.7	0.2	1.9	1.6
Sodium	(mg/l)	8	75	17	94	51	3	54	12	67	46	3	25	3	29	23
Sodium Adsorption Ratio		8	1.86	0.37	2.3	1.4	3	1.43	0.23	1.7	1.3	3	0.73	0.06	0.8	0.7
Percent Sodium		8	34	4	40	29	3	30	2	32	28	3	21	2	22	19
Strontium	(ug/l)	8	953	128	1100	800	3	840	130	990	760	3	473	74	530	390
MAJOR ANIONS																
Bicarbonate	(mg/l)	8	230	24	260	190	3	210	17	230	200	3	170	20	190	150
Carbonate	(mg/l)	7	0	0	0	0	1	0	0	0	0	3	0	0	0	0
Chloride	(mg/l)	8	46	7	60	38	3	31	4	36	29	3	16	2	19	15
Sulfate	(mg/l)	8	201	29	250	160	3	160	44	210	130	3	87	13	99	73
Sulfide	(mg/l)	4	0.15	0.13	0.3	0.0	3	0.1	0.1	0.2	0.0	0	- -	- -	- -	- -
Fluoride	(mg/l)	8	0.38	0.34	1.2	0.2	3	0.30	0.17	0.5	0.2	3	0.50	0.52	1.1	0.2
Bromide	(mg/l)	5	0.16	0.09	0.3	0.1	3	0.1	0.0	0.1	0.1	0	- -	- -	- -	- -
BIOCHEMICAL CONSTITUENTS																
Dissolved Oxygen	(mg/l)	6	9.38	1.52	11.4	7.8	3	8.03	0.25	8.3	7.8	3	7.33	0.31	7.6	7.0
Chemical Oxygen Demand	(mg/l)	8	30	30	96	5	3	32	9	38	22	3	36	12	44	23
Dissolved Organic Carbon	(mg/l)	4	5.5	2.3	8.6	3.4	3	3.7	1.3	5.2	2.9	0	- -	- -	- -	- -
Chlorophyll A	(ug/l)	7	0.487	0.394	0.890	0.000	3	1.24	2.15	3.73	0.000	3	0.407	0.358	0.670	0.000
Chlorophyll B	(ug/l)	7	0.015	0.039	0.104	0.000	3	0.000	0.000	0.000	0.000	3	0.045	0.039<0.071		0.000

TABLE 4-4 (continued)

		BASEFLOW					LOWER BASIN RUNOFF					UPPER BASIN RUNOFF				
		No. of Samples	Mean	Stan. Dev.	Max	Min	No. of Samples	Mean	Stan. Dev.	Max	Min	No. of Samples	Mean	Stan. Dev.	Max	Min
MACRONUTRIENTS																
Ammonia as N	(mg/l)	8	0.024	0.016	0.06	0.01	3	0.003	0.006	0.01	0.00	3	0.013	0.015	0.03	0.00
Nitrite as N	(mg/l)	8	0.003	0.005	0.01	0.00	3	0.003	0.006	0.01	0.00	3	0.003	0.006	0.01	0.00
Nitrate as N	(mg/l)	8	0.043	0.035	0.08	0.01	3	0.137	0.133	0.29	0.06	3	0.057	0.046	0.11	0.03
Total Kjeldahl Nitrogen as N	(mg/l)	8	0.89	1.19	3.8	0.12	3	0.84	0.18	1.0	0.65	3	0.59	0.16	0.76	0.44
Total Phosphorus as P	(mg/l)	8	0.75	1.92	5.5	0.03	3	0.30	0.07	0.36	0.23	3	0.13	0.06	0.18	0.06
Diss. Orthophosphorus as P	(mg/l)	8	0.048	0.122	0.35	0.00	3	0.01	0.01	0.02	0.00	3	0.023	0.012	0.03	0.01
MICRONUTRIENTS																
Boron	(ug/l)	8	68	16	90	40	3	57	12	70	50	3	50	10	60	40
Copper	(ug/l)	5	5.2	5.6	15	2	3	2.3	2.5	5	0	0	- -	- -	- -	- -
Iron	(ug/l)	8	45	56	180	10	3	40	17	50	20	3	173	139	290	20
Manganese	(ug/l)	8	6.3	9.2	20	0	3	6.7	5.8	10	0	3	16.7	5.8	20	10
Zinc	(ug/l)	5	8.4	2.6	10	4	3	13.3	5.8	20	10	0	- -	- -	- -	- -
Molybdenum	(ug/l)	5	1.8	0.8	3	1	3	1.0	1.7	3	0	0	- -	- -	- -	- -
Silica	(mg/l)	8	12.4	2.4	15	7.1	3	12.0	1.0	13	11	3	16.3	2.1	18	14
TRACE METALS																
Aluminum	(ug/l)	8	40	49	160	20	3	0	0	0	0	3	93	83	160	0
Barium	(ug/l)	5	100	122	300	0	3	33	58	100	0	0	- -	- -	- -	- -
Cadmium	(ug/l)	5	0.4	0.9	2	0	3	0.3	0.6	1	0	0	- -	- -	- -	- -
Chromium	(ug/l)	5	5.0	5.0	10	0	3	0	0	0	0	0	- -	- -	- -	- -
Lead	(ug/l)	5	1.6	2.3	5	0	3	0.3	0.6	1	0	0	- -	- -	- -	- -
Lithium	(ug/l)	8	17	7	30	8	3	12	7	20	8	3	10	0	10	10
Mercury	(ug/l)	5	0.0	0.0	0.0	0.0	3	0.0	0.0	0.0	0.0	0	- -	- -	- -	- -
Selenium	(ug/l)	5	0.4	0.6	1	0	3	1.0	0.0	1	1	0	- -	- -	- -	- -
Vanadium	(ug/l)	5	1.1	0.7	2.0	0.3	3	2.0	0.0	2.0	2.0	0	- -	- -	- -	- -
TRACE NON-METALS																
Arsenic	(ug/l)	5	1.8	0.5	2	1	3	2.0	1.7	4	1	0	- -	- -	- -	- -
MBAS	(mg/l)	5	0.08	0.05	0.10	0.00	3	0.03	0.06	0.10	0.00	0	- -	- -	- -	- -
Phenols	(ug/l)	5	2.2	0.8	3	1	3	5.3	2.3	8	4	0	- -	- -	- -	- -
RADIOACTIVE CONSTITUENTS																
Gross Alpha as U-nat., diss.	(ug/l)	5	7.04	2.18	9.8	<3.7	3	- -	- -	<4.9	<4.3	0	- -	- -	- -	- -
Gross Beta as Sr-90/Y-90, diss.	(pCi/l)	5	3.36	2.61	8.0	1.8	3	2.20	1.23	3.6	1.3	0	- -	- -	- -	- -
Gross Beta as Cs-137, diss.	(pCi/l)	5	3.92	3.41	10	2.0	3	2.47	1.34	4.0	<1.5	0	- -	- -	- -	- -



VARIATION IN TIME OF GENERAL CHARACTERISTICS

WHITE RIVER NEAR COLO STATE LINE TO BELOW ASPHALT WASH

OCTOBER 1977 - SEPTEMBER 1978

VTN

FIGURE 4-6

TABLE 4-5

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY — PROCESS DATE IS 03-14-79

STATION NUMBER 09306395 WHITE R. NR. COLO. STATE LINE, UT. — STREAM — SOURCE AGENCY USGS
LATITUDE 400050 LONGITUDE 1090448 DRAINAGE AREA — DATUM 5030.00 — STATE 49 COUNTY 047

SUSPENDED-SEDIMENT, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

Unpublished Records Subject to Revision

DAY	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)
	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
1	---	1500	---	4000	1710	10100	1040	6570	---	190	118	80
2	---	2300	---	3800	1880	10100	---	5700	---	200	102	70
3	---	2800	---	3400	2140	11800	---	4800	---	180	100	69
4	---	2200	---	4500	2180	12200	---	4300	---	160	91	62
5	---	1800	---	5700	2320	13800	---	3600	---	140	79	50
6	---	1900	---	5500	3130	20000	---	2900	---	140	61	35
7	---	1600	---	4700	2130	12300	---	2400	---	130	50	27
8	---	1400	---	4200	2270	13800	---	2200	---	120	61000	412000
9	---	1500	---	3800	1800	10800	---	1900	---	110	32600	5440
10	---	1700	---	3200	---	12000	---	1600	92	92	5050	5710
11	---	1600	---	3400	---	16000	---	1600	79	79	1100	1050
12	---	1400	---	3800	---	20000	---	1800	89	89	400	373
13	---	1400	---	3700	---	19000	---	1700	158	167	---	440
14	---	1600	---	4200	---	17000	550	1450	3100	3780	---	380
15	---	1700	---	7200	---	18000	---	1200	1380	1670	---	330
16	---	1700	---	16000	---	17000	---	1000	552	778	---	340
17	---	1800	---	27000	---	17000	---	960	270	339	---	340
18	---	1800	5680	37300	---	15000	---	1100	179	205	---	350
19	---	1600	4630	23300	1140	11100	---	1200	117	131	---	420
20	---	1400	3480	14300	1040	9580	---	980	155	184	410	486
21	---	1300	3170	13000	720	6240	---	840	169	198	395	459
22	---	1400	3570	16900	500	3970	---	710	208	233	---	460
23	---	1400	3640	18700	---	4900	---	600	252	265	---	420
24	---	1300	3890	23200	---	6000	---	430	223	219	---	410
25	---	1200	4230	30200	---	7300	---	490	194	180	---	380
26	980	1520	3400	23700	---	9000	---	410	175	166	---	380
27	---	2000	2680	16200	---	8800	---	330	141	128	---	370
28	---	3600	2700	16600	---	7100	---	270	150	131	---	340
29	---	3800	2340	12900	---	7200	---	240	149	131	---	350
30	---	4100	2500	13400	1120	7590	---	220	131	109	---	340
31	---	---	2200	12600	---	---	---	210	128	92	---	---
TOTAL	---	56320	---	380400	---	354680	---	53710	---	10736	---	431961

TOTAL LOAD FOR YEAR: 1415067 TONS.

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

TABLE 4-5 (continued)

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY — PROCESS DATE IS 03-14-79

STATION NUMBER 09306395 WHITE R. NR. COLO. STATE LINE, UT. — STREAM SOURCE AGENCY USGS
LATITUDE 400050 LONGITUDE 1090448 DRAINAGE AREA — DATUM 5030.00 STATE 49 COUNTY 047

SUSPENDED-SEDIMENT, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

Unpublished Records
Subject to Revision

DAY	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)	MEAN CONCEN-TRATION (MG/L)	LOADS (T/DAY)
	APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER	
1	---	1500	---	4000	1710	10100	1040	6570	---	190	118	80
2	---	2300	---	3800	1880	10100	---	5700	---	200	102	70
3	---	2800	---	3400	2140	11800	---	4800	---	180	100	69
4	---	2200	---	4500	2180	12200	---	4300	---	160	91	62
5	---	1800	---	5700	2320	13800	---	3600	---	140	79	50
6	---	1900	---	5500	3130	20000	---	2900	---	140	61	35
7	---	1600	---	4700	2130	12300	---	2400	---	130	50	27
8	---	1400	---	4200	2270	13800	---	2200	---	120	61000	412000
9	---	1500	---	3800	1800	10800	---	1900	---	110	32600	5440
10	---	1700	---	3200	---	12000	---	1600	92	92	5050	5710
11	---	1600	---	3400	---	16000	---	1600	79	79	1100	1050
12	---	1400	---	3800	---	20000	---	1800	89	89	400	373
13	---	1400	---	3700	---	19000	---	1700	158	167	---	440
14	---	1600	---	4200	---	17000	550	1450	3100	3780	---	380
15	---	1700	---	7200	---	18000	---	1200	1380	1670	---	330
16	---	1700	---	16000	---	17000	---	1000	552	778	---	340
17	---	1800	---	27000	---	17000	---	960	270	339	---	340
18	---	1800	5680	37300	---	15000	---	1100	179	205	---	350
19	---	1600	4630	23300	1140	11100	---	1200	117	131	---	420
20	---	1400	3480	14300	1040	9580	---	980	155	184	410	486
21	---	1300	3170	13000	720	6240	---	840	169	198	395	459
22	---	1400	3570	16900	500	3970	---	710	208	233	---	460
23	---	1400	3640	18700	---	4900	---	600	252	265	---	420
24	---	1300	3890	23200	---	6000	---	430	223	219	---	410
25	---	1200	4230	30200	---	7300	---	490	194	180	---	380
26	980	1520	3400	23700	---	9000	---	410	175	166	---	380
27	---	2000	2680	16200	---	8800	---	330	141	128	---	370
28	---	3600	2700	16600	---	7100	---	270	150	131	---	340
29	---	3800	2340	12900	---	7200	---	240	149	131	---	350
30	---	4100	2500	13400	1120	7590	---	220	131	109	---	340
31	---	---	2200	12600	---	---	---	210	128	92	---	---
TOTAL	---	56320	---	380400	---	354680	---	53710	---	10736	---	431961

TOTAL LOAD FOR YEAR: 1415067 TONS.

NOTE: NUMBER OF MISSING DAYS OF RECORD EXCEEDED 20% OF YEAR

TABLE 4-6

WHITE RIVER BELOW ASPHALT WASH (Sta. No. 09306700)
SUSPENDED SEDIMENT DISCHARGE
OCTOBER 1977 - SEPTEMBER 1978

	OCTOBER 1977			NOVEMBER 1977			DECEMBER 1977		
	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)
1	169	- -	- -	310	1300	1090	303	- -	- -
2	155	- -	- -	318	735	631	330	- -	- -
3	166	- -	- -	310	769	644	326	1760	1550
4	163	- -	- -	310	733	614	330	1720	1530
5	163	- -	- -	310	812	680	334	* 1230	1110
6	158	330	141	310	1000	837	326	- -	- -
7	201	- -	- -	338	17500	16000	310	- -	- -
8	338	- -	- -	322	3680	3200	244	- -	- -
9	300	- -	- -	318	* 1620	1390	289	- -	- -
10	278	* 3340	2510	307	- -	- -	314	- -	- -
11	251	1160	786	265	1240	887	244	- -	- -
12	251	847	574	265	1190	851	338	- -	- -
13	254	* 643	441	307	958	794	322	* 306	266
14	261	- -	- -	310	1000	837	350	* 1120	1060
15	293	1090	862	293	572	453	326	- -	- -
16	282	- -	- -	293	667	528	318	- -	- -
17	296	965	771	307	809	671	314	- -	- -
18	290	684	536	300	- -	- -	310	- -	- -
19	280	846	640	300	612	496	237	- -	- -
20	280	642	485	296	804	643	183	- -	- -
21	290	717	561	228	- -	- -	160	- -	- -
22	300	1190	964	118	- -	- -	130	- -	- -
23	310	3620	3030	210	- -	- -	118	- -	- -
24	310	2050	1720	350	- -	- -	140	- -	- -
25	300	640	518	370	- -	- -	240	- -	- -
26	300	618	501	380	- -	- -	330	- -	- -
27	300	555	450	362	- -	- -	300	* 350	284
28	289	* 778	607	362	* 1720	1680	260	- -	- -
29	289	611	477	338	1610	1470	260	- -	- -
30	296	1410	1130	330	- -	- -	300	- -	- -
31	293	1680	1330				300	- -	- -

TABLE 4-6 (continued)

WHITE RIVER BELOW ASPHALT WASH (Sta. No. 09306700)
SUSPENDED SEDIMENT DISCHARGE
OCTOBER 1977 - SEPTEMBER 1978

	JANUARY 1978				FEBURARY 1978				MARCH 1978			
	MEAN DISCHARGE (cfs)		MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)		MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)		MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)
1	310		- -	- -	330		- -	- -	390		- -	- -
2	290		- -	- -	310		- -	- -	394	*	1620	1720
3	250	*	992	670	280		- -	- -	370		- -	- -
4	210		- -	- -	300		- -	- -	342		- -	- -
5	200		- -	- -	300		- -	- -	370		- -	- -
6	310		- -	- -	300		- -	- -	382		- -	- -
7	330		- -	- -	300		- -	- -	466		- -	- -
8	330		- -	- -	300		- -	- -	458		- -	- -
9	330		- -	- -	340		- -	- -	495		- -	- -
10	310		- -	- -	320		- -	- -	490		- -	- -
11	310		- -	- -	300		- -	- -	510		- -	- -
12	330	*	91	81	340		- -	- -	430		- -	- -
13	370		- -	- -	380		- -	- -	430		2010	2330
14	360		- -	- -	350	*	690	652	442	*	1950	2330
15	330		- -	- -	360		- -	- -	410		- -	- -
16	300		- -	- -	350		- -	- -	382		- -	- -
17	320		- -	- -	340		- -	- -	358		- -	- -
18	330		- -	- -	350		- -	- -	354		- -	- -
19	330		- -	- -	320		- -	- -	402		- -	- -
20	300		- -	- -	250		- -	- -	490		- -	- -
21	300		- -	- -	270		- -	- -	555		- -	- -
22	300		- -	- -	290		- -	- -	535		- -	- -
23	300		- -	- -	290		- -	- -	610		4240	6980
24	300		- -	- -	270		- -	- -	680		- -	- -
25	280		- -	- -	280		- -	- -	850		- -	- -
26	250	*	382	258	300		- -	- -	590		- -	- -
27	290		- -	- -	350		- -	- -	480		4290	5560
28	310		- -	- -	380		- -	- -	470		1490	1890
29	300		- -	- -					460		1520	1890
30	240	*	302	196					490	*	1850	2450
31	260		- -	- -					505		1630	2220

TABLE 4-6 (continued)

WHITE RIVER BELOW ASPHALT WASH (Sta. No. 09306700)
SUSPENDED SEDIMENT DISCHARGE
OCTOBER 1977 - SEPTEMBER 1978

	APRIL 1978			MAY 1978			JUNE 1978		
	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)
1	535	1330	1920	930	* 5830	14600	2210	* 2570	15300
2	600	- -	- -	912	3410	8400	2090	- -	- -
3	700	- -	- -	876	2970	7020	2090	- -	- -
4	660	- -	- -	918	3290	8150	2180	- -	- -
5	620	2730	4570	1050	4700	13300	2220	* 968	5800
6	636	3160	5430	1070	- -	- -	2510	- -	- -
7	654	3750	6620	1010	- -	- -	2280	- -	- -
8	555	1840	2760	930	- -	- -	2350	- -	- -
9	570	- -	- -	876	- -	- -	2380	* 2100	13500
10	612	1560	2580	816	3720	8200	2480	- -	- -
11	624	1710	2880	786	2400	5090	2890	- -	- -
12	565	* 1410	2150	822	2330	5170	3320	* 3940	35300
13	560	1280	1940	828	2450	5480	3540	8640	82600
14	550	1650	2450	846	- -	- -	3480	- -	- -
15	555	1520	2280	997	* 3380	9100	3520	18400	175000
16	565	1480	2260	1500	- -	- -	3690	9500	94600
17	642	437	757	2100	9440	53500	3730	- -	- -
18	648	523	915	2500	- -	- -	3860	- -	- -
19	630	573	975	2000	9670	52200	3720	* 2460	24700
20	576	861	1340	1600	- -	- -	3410	- -	- -
21	535	1440	2080	1600	- -	- -	3170	* 2470	21100
22	545	2740	4030	1800	2310	11200	3030	- -	- -
23	582	3320	5220	2080	* 4010	22500	3060	* 2440	20200
24	550	2130	3160	2240	- -	- -	3160	- -	- -
25	530	826	1180	2660	- -	- -	3270	- -	- -
26	540	843	1230	2700	* 4520	33000	3400	* 2750	25200
27	630	1190	2020	2380	- -	- -	3440	- -	- -
28	750	3020	6120	2370	- -	- -	2910	* 936	7350
29	870	4040	9490	2150	- -	- -	2740	- -	- -
30	930	3760	9440	2010	* 1690	9170	2670	* 1960	14100
31				2100	- -	- -			

Note: The symbol, *, indicates that a suspended sediment sample was taken manually using the EDI method.

TABLE 4-6 (continued)

WHITE RIVER BELOW ASPHALT WASH (Sta. No. 09306700)
SUSPENDED SEDIMENT DISCHARGE
OCTOBER 1977 - SEPTEMBER 1978

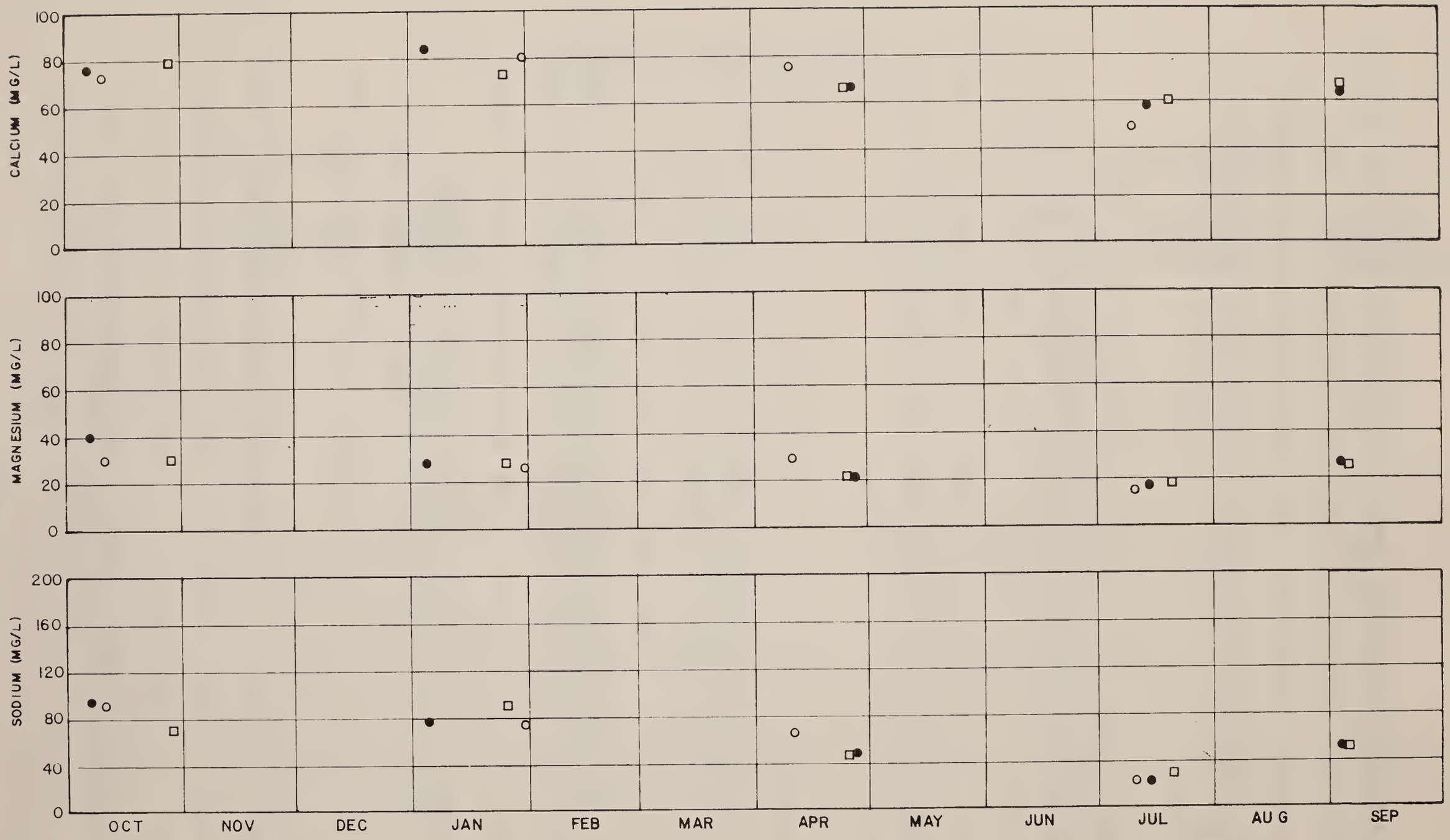
	JULY 1978			AUGUST 1978			SEPTEMBER 1978		
	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)	MEAN DISCHARGE (cfs)	MEAN CONCENTRATION (mg/l)	SEDIMENT DISCHARGE (tons/day)
1	2520	- -	- -	493	* 237	315	256	- -	- -
2	2370	- -	- -	470	- -	- -	256	- -	- -
3	2150	- -	- -	488	- -	- -	256	- -	- -
4	1990	* 1780	9560	470	- -	- -	260	- -	- -
5	1820	- -	- -	443	- -	- -	249	* 201	135
6	1590	- -	- -	439	- -	- -	239	- -	- -
7	1450	- -	- -	430	- -	- -	222	- -	- -
8	1330	- -	- -	373	* 199	200	809	- -	- -
9	1270	- -	- -	365	- -	- -	832	- -	- -
10	1160	* 779	2440	353	- -	- -	413	- -	- -
11	1070	- -	- -	349	* 151	142	345	* 3520	3280
12	1140	- -	- -	345	- -	- -	317	- -	- -
13	1080	* 1970	5740	369	- -	- -	337	- -	- -
14	988	- -	- -	448	- -	- -	345	- -	- -
15	922	- -	- -	401	* 2590	2800	333	- -	- -
16	850	- -	- -	448	- -	- -	333	- -	- -
17	804	- -	- -	457	- -	- -	345	- -	- -
18	826	* 550	1230	397	* 412	442	349	- -	- -
19	934	- -	- -	373	- -	- -	373	* 569	573
20	874	- -	- -	381	- -	- -	425	- -	- -
21	793	* 338	724	393	* 328	348	417	- -	- -
22	727	- -	- -	377	* 332	338	421	* 397	451
23	690	- -	- -	361	- -	- -	413	- -	- -
24	650	- -	- -	341	- -	- -	405	- -	- -
25	650	- -	- -	325	* 275	241	393	- -	- -
26	595	- -	- -	317	- -	- -	385	* 440	457
27	570	- -	- -	321	- -	- -	385	- -	- -
28	524	* 271	383	309	- -	- -	373	- -	- -
29	596	* 307	419	305	- -	- -	369	* 264	263
30	497	- -	- -	309	- -	- -	369	- -	- -
31	502	- -	- -	284	- -	- -			

was estimated to be 1,415,067 tons. The maximum daily discharge during the year at this station was 412,000 tons on September 8th. This occurred during a flash flood. Both records indicate that suspended sediment concentration and discharge follow a direct relationship to streamflow.

Major Cations: The variation in time of the major cations calcium, magnesium, and sodium) is shown in Figure 4-7. The concentration levels of calcium, magnesium, potassium, sodium, and strontium followed the same trend as the concentration of dissolved solids. The Sodium Adsorption Ration (SAR) and the percent of sodium also followed an inverse relationship to streamflow.

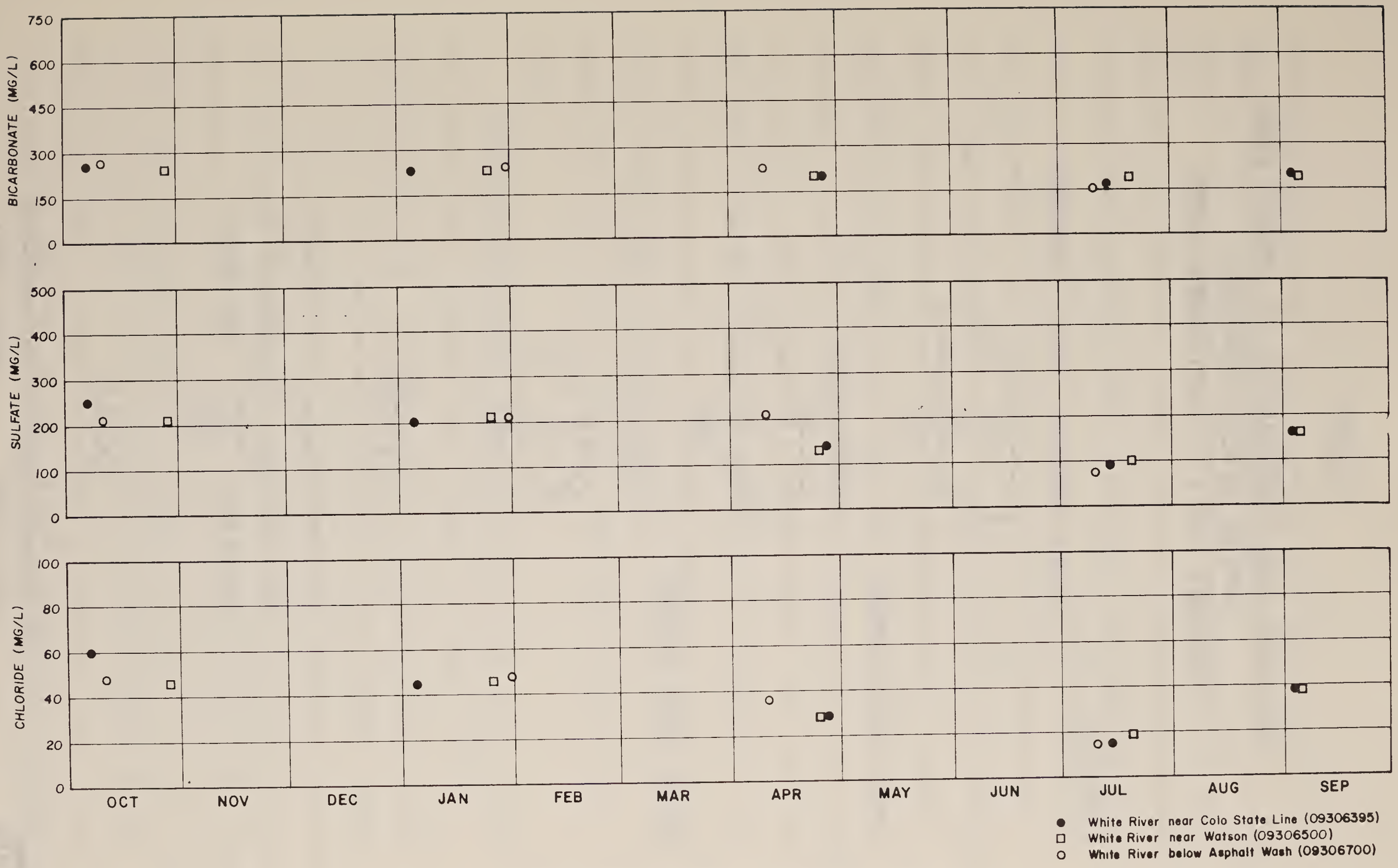
Major Anions: The variation in time of the major anions (bicarbonate, sulfate, and chloride) is shown in Figure 4-8. The concentration levels of chloride and sulfate followed an inverse relationship to streamflow, similar to the trend of the concentration of dissolved solids. The concentration of bicarbonate decreased slightly as streamflow increased. The concentration of carbonate was zero for all of the analyses. Sulfide and bromide levels were relatively constant throughout the year. Fluoride levels showed considerable fluctuation. Concentrations of fluoride ranged from 0.2 mg/l to 0.5 mg/l, except for values of 1.2 mg/l and 1.1 mg/l on October 10, 1977 and July 10, 1978, respectively, at station 6700.

The balance and distribution of the major ions during each of the flow periods is shown in Figure 4-9. The Stiff diagrams illustrate the decrease in the concentrations of all of the major ions due to the dilution effect of snowmelt runoff. They also illustrate the differences in the distributions of the ions between the three flow periods.



VARIATION IN TIME OF MAJOR CATIONS
WHITE RIVER NEAR COLO STATE LINE TO BELOW ASPHALT WASH
OCTOBER 1977 - SEPTEMBER 1977

FIGURE 4-7



VARIATION IN TIME OF MAJOR ANIONS
WHITE RIVER NEAR COLO STATE LINE TO BELOW ASPHALT WASH
OCTOBER 1977 – SEPTEMBER 1978

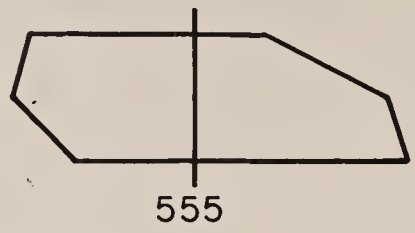
FIGURE 4-8

FIGURE 4-9

BALANCE AND DISTRIBUTION OF MAJOR IONS
WHITE RIVER STATIONS
OCTOBER 1977 – SEPTEMBER 1978

BASEFLOW

OCTOBER – FEBRUARY, AUGUST, SEPTEMBER

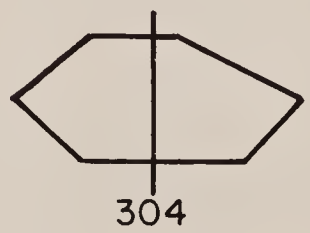


LOWER BASIN RUNOFF

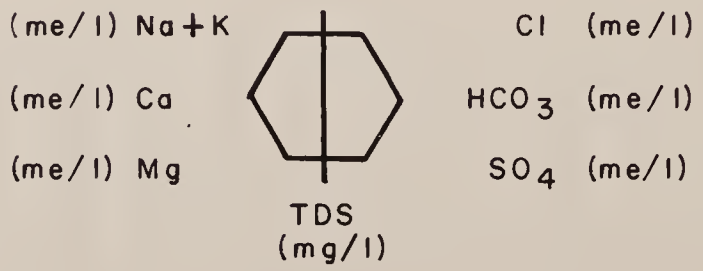
MARCH, APRIL

UPPER BASIN RUNOFF

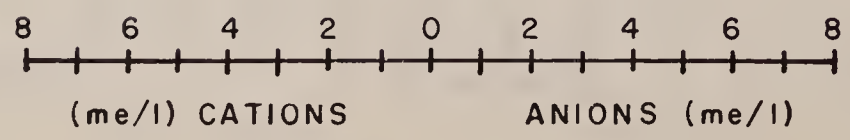
MAY – JULY



LEGEND

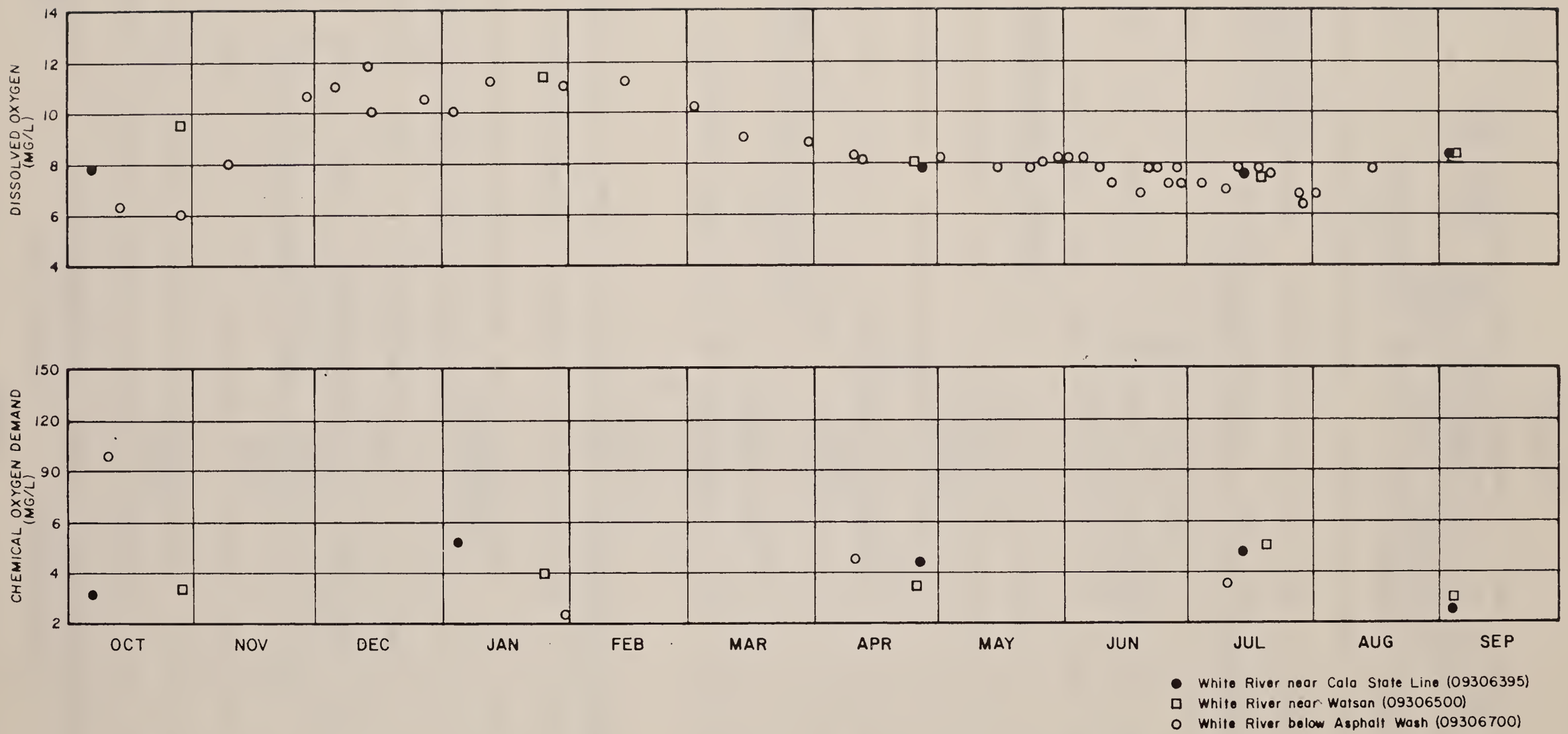


SCALE



During upper basin runoff the water would be classed as calcium-bicarbonate type; whereas, during baseflow and lower basin runoff, no single cation or anion was dominant. The data from the Baseline study indicated that during lower basin runoff, sodium and sulfate were present in a greater proportion than Figure 4-9 indicates. The water quality samples at stations 6395, 6500, and 6700 were collected on April 26, April 25, and April 10, respectively. The data for the April 10th sample shows some differences from the data for the April 25th and 26th samples (See Figures 4-7 and 4-8). The lower basin runoff period is considered to have ended and the upper basin runoff period to have begun when the streamflow at station 6395 no longer exceeds the streamflow at station 4500 on the White River near Meeker. This transition was occurring during late April. Therefore, it is probable that the samples during late April are partially affected by some runoff contribution from the upper basin. Since the Stiff diagrams in Figure 4-9 are based on the mean values in Table 4-4, they also show this partial effect.

Biochemical Constituents: The variation in time of some biochemical constituents (dissolved oxygen and Chemical Oxygen Demand) is shown in Figure 4-10. The higher values of dissolved oxygen occurred during the winter when the water temperature was the coldest, and the lower values occurred during the late summer when the water temperature was the warmest. There were no measurements made during the year that were below 6.0 mg/l. The values of Chemical Oxygen Demand (COD) ranged from 5 mg/l to 48 mg/l, except for one value of 96 mg/l on October 10, 1977 at station 6700. Precipitation and streamflow records indicate that a rapid rise in streamflow occurred on October 8th due to thunderstorm runoff on October 6th and 7th. The high COD value on October



VARIATION IN TIME OF BIOCHEMICAL CONSTITUENTS

WHITE RIVER NEAR COLO STATE LINE TO BELOW ASPHALT WASH

OCTOBER 1977 - SEPTEMBER 1978

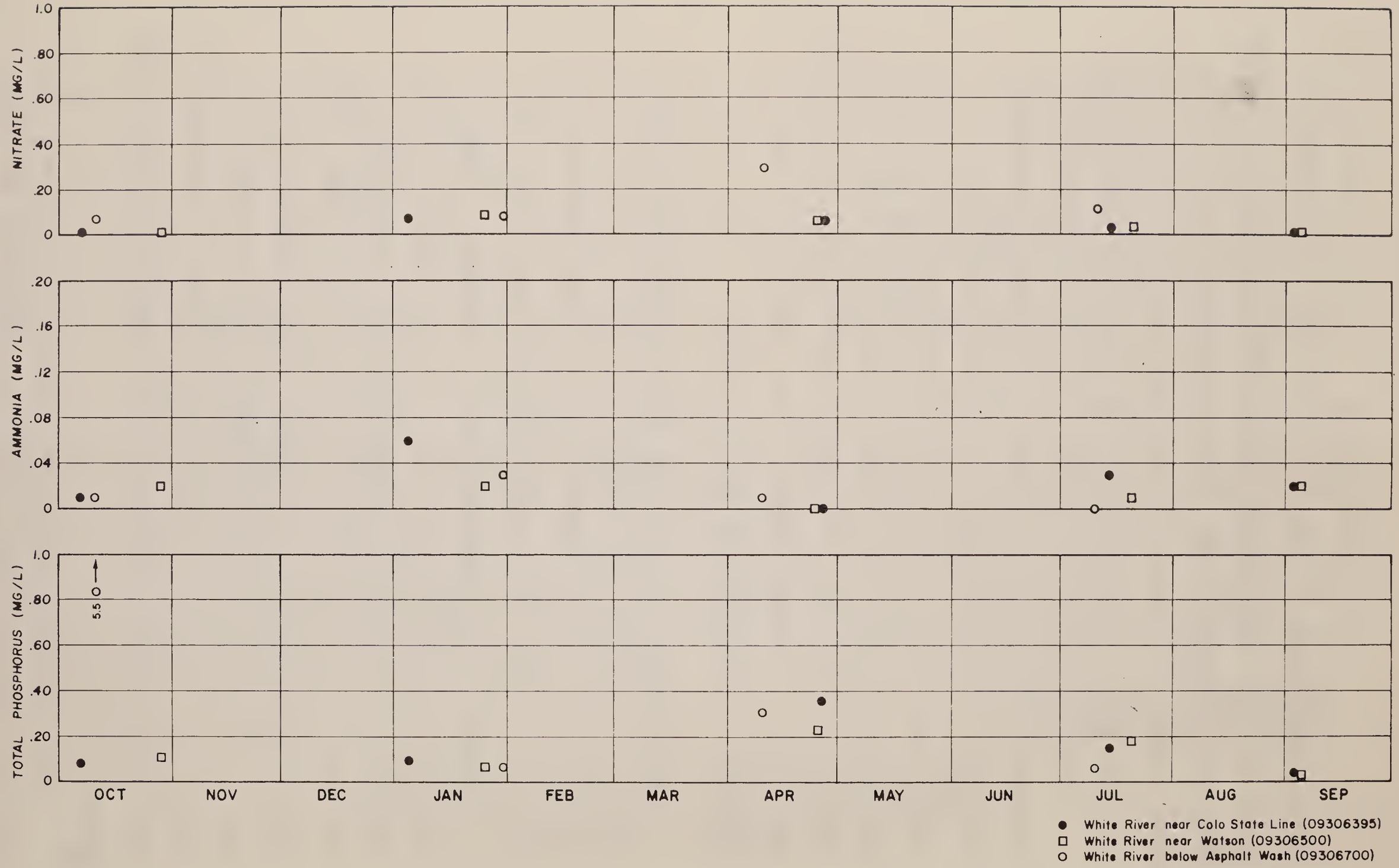
FIGURE 4-10

10th was probably due to large amounts of organic material being washed into the river by thunderstorm runoff. Dissolved organic carbon (DOC) values averaged 5.5 mg/l during baseflow and 3.7 during lower basin runoff. The maximum value of 8.6 mg/l occurred on October 10th at station 6700, and was probably due to the reasons discussed above.

The maximum value of chlorophyll A (3.73 ug/l) was detected on April 26th at station 6395. The rest of the values of chlorophyll A were below 1 ug/l. Chlorophyll A is the preferred indicator to estimate algal biomass. Chlorophyll B was detected only once (0.104 ug/l) on January 25th at station 6500. Chlorophyll B is also found in planktonic algae, but it is not the preferred indicator for estimating algal biomass. ("Standard Methods For the Examination of Water and Wastewater," 14 Edition, APHA, et., al., 1975)

Macronutrients: The variation in time of some macronutrients (nitrate, ammonia, and total phosphorus) is shown in Figure 4-11. Nitrate concentrations varied from 0.01 mg/l to 0.29 mg/l during the year. The maximum value occurred during lower basin runoff. The nitrate values were not especially high during January. Ammonia concentrations varied from 0.00 mg/l to 0.06 mg/l, with the maximum value occurring in January. The concentration of nitrite was low throughout the year, with values of 0.00 mg/l and 0.01 mg/l. Total Kjeldahl nitrogen (ammonia plus organic nitrogen) concentrations generally increased during high streamflow (snowmelt runoff). The maximum value (3.8 mg/l) occurred on October 10th at station 6700. It was probably caused by thunderstorm runoff, which was discussed in the previous section.

Total phosphorus concentrations generally increased during high streamflow (snowmelt runoff). Again, the maximum value (5.5 mg/l)



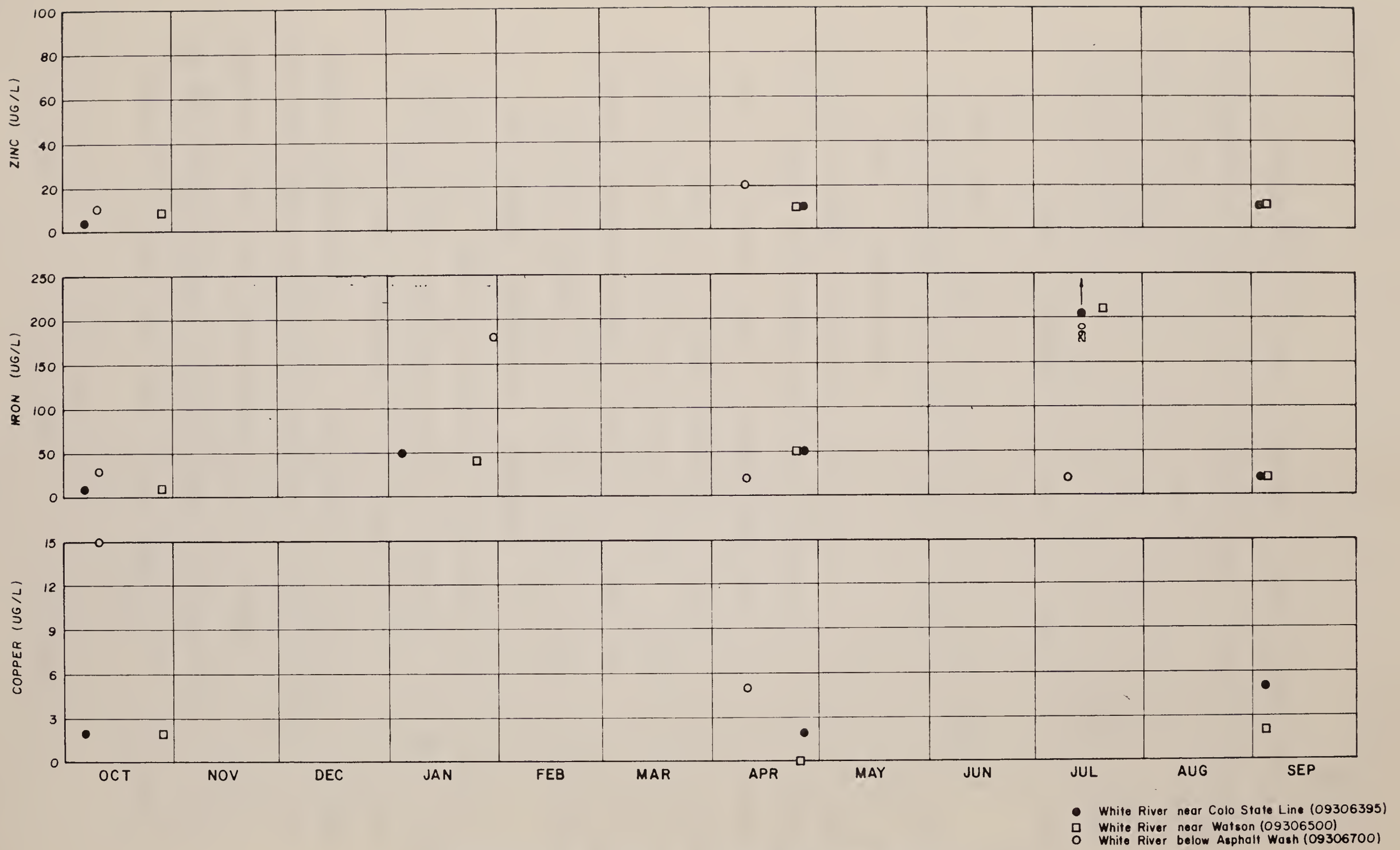
VARIATION IN TIME OF REPESENTATIVE MACRONUTRIENTS
WHITE RIVER NEAR COLO STATE LINE TO BELOW ASPHALT WASH
OCTOBER 1977 – SEPTEMBER 1978

FIGURE 4-11

occurred on October 10th at station 6700, for the same reason as discussed previously. The concentrations of dissolved orthophosphorus ranged from 0.00 mg/l to 0.03 mg/l, except for a value of 0.35 mg/l on January 4th at station 6395. This value is suspect because the value of total phosphorus (0.10 mg/l) from the same analysis does not seem to be unusual in comparison to other total phosphorus values.

Micronutrients: The variation in time of some micronutrients (zinc, iron, and copper) is shown in Figure 4-12. Concentrations of zinc varied from 4 ug/l to 20 ug/l. Concentrations of copper varied from 0 ug/l to 15 ug/l. The maximum value of copper occurred on October 10th at station 6700, and may have been another effect of the thunderstorm runoff. The concentrations of zinc and copper did not show a clear relationship to streamflow, however the amount of data available was limited. The concentrations of iron varied from 10 ug/l to 290 ug/l. These values seem to show a general trend of increasing with higher streamflow, however, there is considerable variation.

The values of boron, manganese, and molybdenum showed little variation throughout the year, and ranged from 40 ug/l to 90 ug/l, 0 ug/l to 20 ug/l, and 0 ug/l to 3 ug/l, respectively. Silica values ranged from 7.1 mg/l to 18 mg/l. The minumum value for silica occurred on January 30th at station 6700. It is less than the minimum from the period of record for the White River stations (8.6 mg/l); also it appears to be anomalous in comparison to the rest of data during the 1978 water year. The maximum value for silica occurred on July 20th at station 6500. It is slightly greater than the maximum for the period



VARIATION IN TIME OF SOME MICRONUTRIENTS
WHITE RIVER NEAR COLO STATE LINE TO BELOW ASPHALT WASH
OCTOBER 1977 - SEPTEMBER 1978

FIGURE 4-12

of record for the White River stations (17 mg/l). There is no clear explanation for the greater variation in the silica values during 1978 than during the Baseline period.

Trace Metals: The concentrations of aluminum, barium and lithium ranged from 0 ug/l to 160 ug/l, 0 ug/l to 300 ug/l, and 8 ug/l to 30 ug/l, respectively, during the year. These parameters do not show clear relationships to streamflow. The concentrations of cadmium, chromium, lead, selenium, and vanadium were very low and showed little variation during the year. Mercury was undetected in all of the analyses.

Trace Non-Metals: The concentrations of arsenic ranged from 1 ug/l to 4 ug/l during the year. Values of Methylene Blue Active Substances (MBAS) ranged from 0.00 mg/l to 0.10 mg/l during the year. The concentrations of phenols ranged from 1 ug/l to 3 ug/l during baseflow, and from 4 ug/l to 8 ug/l during lower basin runoff.

Radioactive Constituents: The maximum value of dissolved gross alpha as Uranium-natural was 9.8 ug/l, and occurred on October 10th at station 6700. The maximum values of dissolved gross beta as Strontium-90/Yittrium-90 and as Cesium-137 were 8.0 picocuries/liter (pCi/l) and 10 pCi/l, respectively. These values also occurred on October 10th at station 6700. It is possible that this is another effect of the thunderstorm runoff.

Water Quality: Evacuation Creek (Station 6430)

The water quality data from station 6430 near the mouth of Evacuation Creek are summarized in Table 4-7. Since none of the samples during the year were collected during high streamflow, the summary is

TABLE 4-7

SUMMARY OF EVACUATION CREEK WATER QUALITY
BASEFLOW
OCTOBER 1977 - SEPTEMBER 1978

		No. of Samples	Mean	Stan. Dev.	Max	Min
GENERAL CHARACTERISTICS						
Total Alkalinity as $CaCO_3$	(mg/l)	5	366	166	430	160
Dissolved Solids, Residue at 180 C	(mg/l)	5	3734	194	3990	3530
Dissolved Solids, Calc. Sum	(mg/l)	5	3540	51	3580	3460
Total Hardness as $CaCO_3$	(mg/l)	5	1100	0	1100	1100
Noncarbonate Hardness as $CaCO_3$	(mg/l)	5	734	106	920	660
pH	(units)	5	7.88	0.13	8.1	7.8
Specific Conductance	(umhos/cm)	5	4520	383	5000	4100
Streamflow	(cfs)	5	0.14	0.20	0.50	0.03
Temperature	(^oC)	5	16.3	14.3	32.0	0.5
Turbidity	(JTU)	5	1.8	0.5	2	1
Color	(PCU)	5	8	3	11	5
MAJOR CATIONS						
Calcium	(mg/l)	5	166	17	190	150
Magnesium	(mg/l)	5	166	9	170	150
Potassium	(mg/l)	5	9.3	1.6	11	7.0
Sodium	(mg/l)	5	736	40	790	680
Sodium Adsorption Ratio		5	9.6	0.4	10	9.0
Percent Sodium		5	58.8	1.5	61	57
Strontium	(ug/l)	5	3880	342	4300	3600
MAJOR ANIONS						
Bicarbonate	(mg/l)	5	446	145	530	190
Carbonate	(mg/l)	5	0	0	0	0
Chloride	(mg/l)	5	42	18	54	10
Sulfate	(mg/l)	5	2180	84	2300	2100
Sulfide	(mg/l)	3	0.27	0.46	0.8	0.0
Fluoride	(mg/l)	5	0.88	0.11	1.0	0.7
Bromide	(mg/l)	3	0.40	0.17	0.5	0.2
BIOCHEMICAL CONSTITUENTS						
Dissolved Oxygen	(mg/l)	5	9.0	1.5	10.6	7.2
Chemical Oxygen Demand	(mg/l)	5	35	15	60	23
Dissolved Organic Carbon	(mg/l)	3	9.8	1.1	11	9.0
Chlorophyll A	(ug/l)	5	1.714	1.727	4.42	0.000
Chlorophyll B	(ug/l)	5	0.020	0.029	0.064	0.000

TABLE 4-7 (continued)

		No. of Samples	Mean	Stan. Dev.	Max	Min
MACRONUTRIENTS						
Ammonia as N	(mg/l)	5	0.020	0.014	0.04	0.00
Nitrite as N	(mg/l)	5	0.006	0.009	0.02	0.00
Nitrate as N	(mg/l)	5	0.18	0.37	0.84	0.01
Total Kjeldahl Nitrogen as N	(mg/l)	5	0.62	0.22	0.91	0.42
Total Phosphorus as P	(mg/l)	5	0.008	0.008	0.02	0.00
Diss. Orthophosphorus as P	(mg/l)	5	0.006	0.006	0.01	0.00
MICRONUTRIENTS						
Boron	(ug/l)	5	2220	192	2400	1900
Copper	(ug/l)	3	2.3	0.6	3	2
Iron	(ug/l)	5	36	11	50	20
Manganese	(ug/l)	5	112	70	220	40
Zinc	(ug/l)	3	20	0	20	20
Molybdenum	(ug/l)	3	45	22	70	30
Silica	(mg/l)	5	10.7	2.1	14	8.4
TRACE METALS						
Aluminum	(ug/l)	5	10	10	20	0
Barium	(ug/l)	3	33	58	100	0
Cadmium	(ug/l)	3	0	0	0	0
Chromium	(ug/l)	3	8.3	2.9	10	0
Lead	(ug/l)	3	0.7	1.2	2	0
Lithium	(ug/l)	5	106	54	140	10
Mercury	(ug/l)	3	0.0	0.0	0.0	0.0
Selenium	(ug/l)	3	0.7	1.2	2	0
Vanadium	(ug/l)	3	0.37	0.64	1.1	0.0
TRACE NON-METALS						
Arsenic	(ug/l)	3	2.0	1.0	3	1
MBAS	(mg/l)	3	0.07	0.06	0.10	0.00
Phenols	(ug/l)	3	1.7	0.6	2	1
RADIOACTIVE CONSTITUENTS						
Gross Alpha as U-nat., diss.	(ug/l)	3	42.3	19.7	65	<29
Gross Beta as Sr-90/Y-90, diss.	(pCi/l)	3	14.0	4.1	18	<9.9
Gross Beta as Cs-137, diss.	(pCi/l)	3	16.0	5.0	21	<11

only applicable to baseflow. As in the summary of White River water quality, the parameters are grouped according to general catagories.

General Characteristics: The concentrations of dissolved solids ranged from 3460 mg/l to 3580 mg/l, while the streamflow ranged from 0.03 cfs to 0.50 cfs. Levels of pH and total hardness showed little variation, and averaged 7.88 units and 1100 mg/l, respectively. The values of alkalinity and noncarbonate hardness showed considerable variation, and ranged from 116 mg/l to 366 mg/l and 660 mg/l to 920 mg/l, respectively. Total hardness is the sum of carbonate hardness and noncarbonate hardness. Carbonate hardness is that portion of the total hardness equivalent to the alkalinity (when both are expressed in equivalents of $CaCO_3$). If the hardness exceeds the alkalinity, the excess is termed noncarbonate hardness.

The measurements of mean daily water temperature and instantaneous specific conductance are shown in Figure 4-5. Temperature followed an annual sinusoidal pattern. The measurements of instantaneous specific conductance illustrate an inverse relationship to streamflow, with the minimum value occurring in early spring during snowmelt runoff.

The values of instantaneous suspended sediment concentration and discharge during the 1978 water year are shown in Table 4-8. The mean daily values of suspended sediment discharge were estimated from these measurements. The monthly and annual summary is shown in Table 4-9. The maximum mean daily suspended sediment discharge was estimated to have been 33,000 tons/day on August 13, 1978. The total annual discharge was estimated to have been 56,264 tons. Most of the total annual discharge occurred during the runoff from three large thunderstorms in October, November and August.

TABLE 4-8

Unpublished Records
Subject to Revision

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY — PROCESS DATE 03/10/7
09306430 - EVACUATION CR NR MOUTH NR WATSON,UT — DISTRICT CODE 49

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED SEDIMENT

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	TEMPER-ATURE (DEG C) (00010)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	SEDI-MENT DIS-CHARGE, SUS-PENDED (T/DAY) (80155)
OCT , 1977					
27...	1540	.06	16.5	121	.02
NOV					
15...	1530	.07	11.0	106	.02
FEB , 1978					
22...	1020	.05	.0	92	.01
MAR					
07...	1530	3.6	11.0	3090	30
APR					
27...	1200	.50	12.0	16	.02
SEP					
07...	1240	.04	25.0	18	.00

TABLE 4-9

EVACUATION CREEK NEAR MOUTH (STA. NO. 09306430)
SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)
OCTOBER 1977-SEPTEMBER 1978

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Total	12,021	10,470	0.38	0.31	2.25	217.0	76.95	0.85	0.30	368.29	33,106	0.00
Maximum	12,000	10,000	0.02	0.01	1.0	33	17	0.10	0.01	350	33,000	0.00
Minimum	0.02	0.00	0.01	0.01	0.00	1.0	0.02	0.01	0.01	0.01	0.00	0.00

Water Year 1978

Total	56,263.89 tons
Maximum	33,000 tons/day
Minimum	0.00 tons/day

Source: USGS - Water Resources Divison, Salt Lake City, Utah

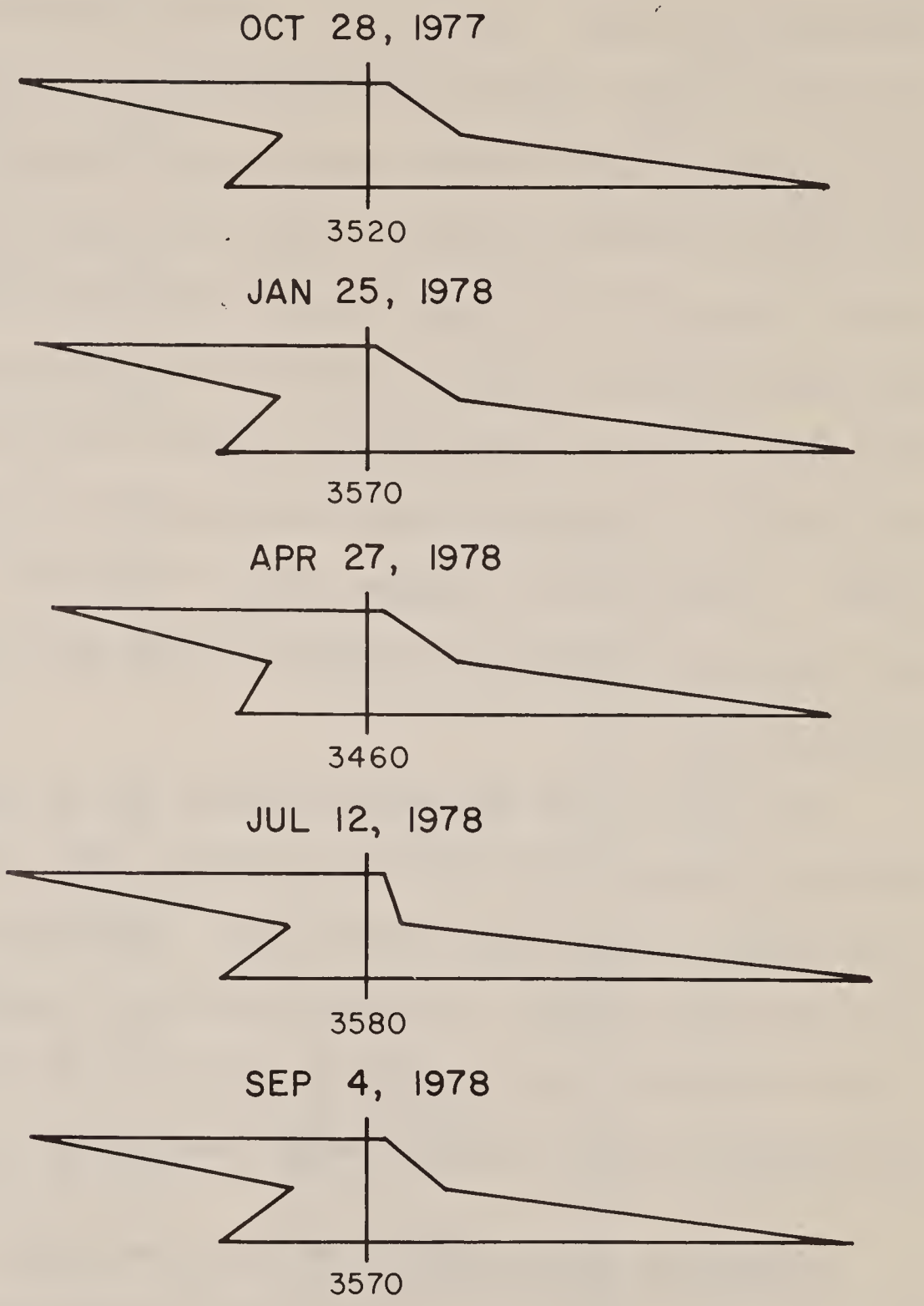
Major Cations and Anions: The balance and distribution of the major ions for each of the samples during the year is shown in Figure 4-13. The variation of the major ions was quite small, with the exception of bicarbonate. The concentrations of bicarbonate varied from 190 mg/l to 530 mg/l. Figure 4-13 illustrates that during April (just after the snowmelt runoff period) the concentrations of calcium and bicarbonate increased slightly from January, while sodium, magnesium, and sulfate decreased slightly. There was no significant thunderstorm runoff during the time between the April and July samples. Therefore, the concentrations of sodium, magnesium, and sulfate increased slightly from April, while calcium decreased slightly and bicarbonate decreased considerably. Significant runoff did occur in August due to thunderstorms. Therefore, the September sample illustrates ion distribution and concentrations which are similar to those for the October and January samples.

The values of SAR and percent sodium, and the concentrations of strontium showed little variation during the year. They averaged 9.6, 58.8%, and 3880 ug/l, respectively. Carbonate levels were zero for all of the analyses. Fluoride and bromide concentrations showed little variation, and averaged 0.88 mg/l and 0.40 mg/l, respectively. The concentrations of sulfide ranged from 0.0 mg/l to 0.8 mg/l.

Biochemical constituents: The dissolved oxygen values varied from 7.2 mg/l to 10.6 mg/l, and COD values varied from 23 mg/l to 60 mg/l. The maximum value of COD occurred in July. The concentration of DOC showed little variation, and averaged 9.8 mg/l. Chlorophyll A was high in October (2.27 ug/l) and in July (4.42 ug/l). Chlorophyll B was highest in July (0.064 ug/l).

FIGURE 4-13

BALANCE AND DISTRIBUTION OF MAJOR IONS EVACUATION CREEK NEAR MOUTH (STATION 6430) BASEFLOW, OCTOBER 1977 – SEPTEMBER 1978



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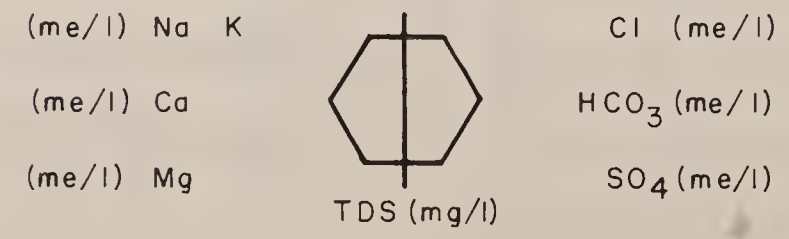

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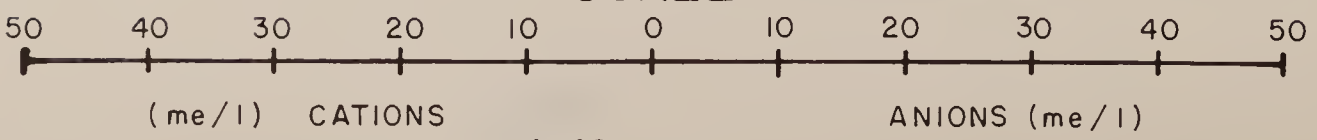


Micronutrients: All of the micronutrients showed little variation during the year, except for manganese, which ranged from 40 ug/l to 220 ug/l. The minimum value of manganese occurred in July, and the maximum value occurred in October.

Trace Metals: All of the trace metals showed little variation during the year, except for lithium. The concentrations of lithium ranged between 120 ug/l and 140 ug/l, except for the value of 10 ug/l during April.

Trace Non-metals: The values of arsenic, MBAS, and phenols showed little variation during the year.

Radioactive Constituents: The maximum value of dissolved gross alpha as Uranium-natural (65 ug/l) occurred during September. The maximum values of gross beta as Strontium-90/Yittrium-90 (18 pCi/l) and as Cesium-137 (21 pCi/l) occurred during October.

Water Quality: Dry Washes

No water quality samples were collected at station 6610 at the mouth of Southam Canyon, because the only flow event during the year occurred at night and the flow was too small for the single-stage sampler to collect a sample. The maximum instantaneous specific conductance during this flow event was estimated to have been approximately 300 umhos/cm (from the record of the automatic recorder and probe).

4.1.1.4 Conclusions. In the December 1976 Work Plan, certain hypotheses were presented to be tested. These hypotheses concern themselves mostly with comparisons of the most recent year's data with the data from the Baseline period (and the period of record). The purpose is to check for significant differences between the sets of data, so that the continuity between the Baseline work and future monitoring periods is maintained.

Comparison of Physical and Chemical Composition of the Surface Water Between the White River stations (6395, 6500, and 6700) During the 1978 Water Year

The streamflow values for these stations showed very little variation between them during the year. There was a very small increase (1.1%) in the total annual runoff between the upstream station (6395) and the downstream station (6700).

The records of suspended sediment concentration and discharge at stations 6395 and 6700 were prepared independently by the USGS and WRSP. The days of record which are comparable (i.e., samples collected at both stations which represent similar points on the streamflow hydrograph) indicate that suspended sediment discharge at the downstream station (6700) was usually equal to or greater than the discharge at the upstream station (6395). This trend was the same during baseflow and during peak flow. The percentage of increase in the downstream direction was highly variable. Data collected at these two stations during future monitoring periods should define the relationship of suspended sediment more clearly than at the present time.

Analysis of Variance (ANOVA) tests at the 90% confidence level were performed on the water quality data during baseflow between the three stations. There were six failures out of the 58 parameters

tested. These were: copper, cadmium, selenium, arsenic, dissolved gross beta as Strontium-90/Yittrium-90, and dissolved gross beta as Cesium-137. The failures of cadmium, selenium, and arsenic do not represent significant differences between the stations; rather, they are the result of a limited amount of data being available for the ANOVA tests. The failures of the other three parameters were caused by high values from the October 10th sample at station 6700 in comparison to the values from the samples at the other two stations. The October 10th sample was collected two days after a significant peak due to thunderstorm runoff. None of the other samples were collected under similar conditions. The higher values were probably a temporary effect of the thunderstorm runoff. These values were not greater than the maximums for baseflow during the Baseline period.

No ANOVA tests could be performed for the lower basin runoff and the upper basin runoff data, because there was only one sample collected at each station for each period. Considering that the samples were taken on different days with the streamflow changing rapidly, the data do not show significant differences in water quality between the three stations.

In summary, the data from the three White River stations (6395, 6500, and 6700) did not exhibit significant differences in the physical or chemical composition of the White River at these locations during the 1978 water year. This has been the general conclusion throughout the period of record.

Comparison of Physical and Chemical Composition of the Surface Water Between the Baseline Period and the 1978 Water Year

White River

The flow regime during 1978 was similar to the regime during

both years of the Baseline Period. The maximum mean daily streamflow during the 1978 water year [109 m^3/sec (3860 cfs) at station 6700] was comparable to the value during the Baseline Period [124 m^3/sec (4380 cfs) at station 6700]. The minimum mean daily streamflow [2.72 m^3/sec (96 cfs) at station 6500] was slightly less than during the Baseline period [4.16 m^3/sec (147 cfs) at station 6400]. The average total annual runoff during the 1978 water year [65,700 hectare-meter (532,300 acre-feet)] was less than during the 1975 water year [68,200 hectare-meter (552,800 acre-feet)] and greater than during the 1976 water year [49,100 hectare-meter (398,400 acre-feet)].

The relationship of suspended sediment concentration and discharge to streamflow during the 1978 water year was similar to the relationship during the Baseline period. The maximum mean daily value of suspended sediment concentration (61,000 mg/l at station 6395 on September 8th) during 1978 was greater than the maximum instantaneous value (38,400 mg/l at station 6500 on August 2, 1976) during the Baseline period. It occurred during a flash flood with a peak flow of 91.7 m^3/sec (3240 cfs) at station 6700. Total annual suspended sediment discharge was not estimated during the Baseline period, so no comparison can be made with the 1978 water year.

The water quality data from the White River stations was compared to the Baseline data using ANOVA tests at the 90% confidence level. The results are summarized in Table 4-10. For the baseflow data, there were 12 failures out of 57 tests. Most of the failures are attributable to unusual values from the October 10th sample at station 6700. As discussed earlier, these values were probably due to thunderstorm

TABLE 4-10

RESULTS OF ANOVA TESTS FOR SIGNIFICANT DIFFERENCE
WHITE RIVER WATER QUALITY

		BASEFLOW	LOWER BASIN RUNOFF	UPPER BASIN RUNOFF
GENERAL CHARACTERISTICS				
Total Alkalinity as $CaCO_3$	(mg/l)		X	
Dissolved Solids, Calc. Sum	(mg/l)	X	X	
Total Hardness as $CaCO_3$	(mg/l)	X		X
Noncarbonate Hardness as $CaCO_3$	(mg/l)		X	
pH	(units)		X	
Specific Conductance	(umhos/cm)	X		X
Streamflow	(cfs)		X	X
Temperature	(^oC)	X		X
Turbidity	(JTU)			X
Color	(PCU)		X	
MAJOR CATIONS				
Calcium	(mg/l)		X	
Magnesium	(mg/l)		X	
Potassium	(mg/l)		X	
Sodium	(mg/l)		X	X
Sodium Adsorption Ratio				
Percent Sodium				
Strontium	(ug/l)			
MAJOR ANIONS				
Bicarbonate	(mg/l)		X	
Carbonate	(mg/l)			
Chloride	(mg/l)		X	
Sulfate	(mg/l)	X	X	
Sulfide	(mg/l)			- -
Fluoride	(mg/l)			X
Bromide	(mg/l)			- -
BIOCHEMICAL CONSTITUENTS				
Dissolved Oxygen	(mg/l)			
Chemical Oxygen Demand	(mg/l)	X		
Dissolved Organic Carbon	(mg/l)			- -
Chlorophyll A	(ug/l)	X		X
Chlorophyll B	(ug/l)	X		X

TABLE 4-10 (continued)

		BASEFLOW	LOWER BASIN RUNOFF	UPPER BASIN RUNOFF
MACRONUTRIENTS				
Ammonia as N	(mg/l)			
Nitrite as N	(mg/l)			
Nitrate as N	(mg/l)			
Total Kjeldahl Nitrogen as N	(mg/l)	X		
Total Phosphorus as P	(mg/l)	X	X	
Diss. Orthophosphorus as P	(mg/l)			
MICRONUTRIENTS				
Boron	(ug/l)		X	
Copper	(ug/l)			- -
Iron	(ug/l)			X
Manganese	(ug/l)			X
Zinc	(ug/l)			- -
Molybdenum	(ug/l)			- -
Silica	(mg/l)			X
TRACE METALS				
Aluminum	(ug/l)	X	X	X
Barium	(ug/l)			- -
Cadmium	(ug/l)			- -
Chromium	(ug/l)			- -
Lead	(ug/l)			- -
Lithium	(ug/l)			
Mercury	(ug/l)			- -
Selenium	(ug/l)			- -
Vanadium	(ug/l)			- -
TRACE NON-METALS				
Arsenic	(ug/l)		X	- -
MBAS	(mg/l)	X		- -
Phenols	(ug/l)			- -
RADIOACTIVE CONSTITUENTS				
Gross Alpha as U-nat., diss.	(ug/l)		- -	- -
Gross Beta as Sr-90/Y-90, diss.	(pCi/l)		X	- -
Gross Beta as Cs-137, diss.	(pCi/l)			- -

LEGEND:
X indicates failure of Analysis of Variance (one-way) test at the 90% confidence level
- - indicates that test could not be made due to lack of data

runoff. There were 16 failures out of 56 tests for the lower basin runoff data. The samples collected on April 25th and 26th were affected by upper basin runoff because they were collected during the transition from lower basin runoff to upper basin runoff. Most of the failures are attributed to data from these two sample analyses. For the upper basin runoff data, there were 13 failures out of 38 tests. All three of these samples were collected during the decline from peak flow.

Although the relatively high ANOVA test failure rates indicate some significant differences in water quality between the 1978 water year and the Baseline period, these differences should be attributed to the hydrologic system's response to variations in climatic conditions rather than changes in the hydrologic system. The combination of the results from similar streamflow periods will help to define the natural variations of water quality.

Evacuation Creek (station 6430)

The flow regime of Evacuation Creek during the 1978 water year was similar to the regime during the Baseline period. The maximum mean daily streamflow during the year [1.87 m^3/sec (66 cfs)] was comparable to the maximum during the Baseline period [2.49 m^3/sec (88 cfs)]. Minimum mean daily streamflow values of zero occurred during the 1978 water and during the Baseline period. Total annual runoff during the year [53.9 hectare-meter (437 acre-feet)] was considerably less than during the 1975 water year [101 hectare-meter (817 acre-feet)] and during the 1976 water year [138 hectare-meter (1120 acre-feet)].

The discharge of suspended sediment during the 1978 water year was similar to previous years of record. Most of the annual discharge occurred during the runoff from a few large thunderstorms. The estimated

total annual discharge during the 1978 water year (56,264 tons) was less than during the 1977 water year (89,052 tons). The estimated maximum mean daily discharge during 1978 (33,000 tons/day) was about the same as during 1977 (35,700 tons/day). The values of instantaneous suspended sediment concentration and discharge during the 1978 water year were similar to comparable values during the Baseline period.

The water quality data during the year were similar to the data collected during the Baseline period. Only five out of 57 parameters had maximum or minimum values during the year which were outside of the ranges of data from the Baseline period. These parameters are noncarbonate hardness, strontium, chloride, manganese and lithium. The Stiff diagrams shown in Figure 4-13 are similar to those shown in the Final Environmental Baseline Report (FEBR). This supports the conclusion that the water quality of Evacuation Creek at station 6430 during the 1978 water year was not significantly different from the water quality during the Baseline period.

Dry Washes

Both the number of flow events and the total annual runoff during the 1978 water year were less than during the Baseline period at the stations at the mouths of Southam Canyon, Hell's Hole Canyon, and Asphalt Wash. Streamflow in these washes showed considerable variation during the Baseline period, which is to be expected for this type of climate and terrain. The differences between the 1978 water year and the Baseline period are the result of the hydrologic system's response to climatic variations rather than changes in the hydrologic system.

No suspended sediment or water quality samples were collected during the year at station 6610 at the mouth of Southam Canyon.

4.1.2 Deep Aquifer Water

The aquifer monitoring program, like the surface water program, is based on a combination of WRSP and USGS efforts. Division of responsiblility is shown in Table 4-11.

4.1.2.1 Objectives. The objectives of this monitoring element are to extend water level data so as to provide continuity between the Baseline work and future monitoirng periods, and to investigate long-term water level trends.

4.1.2.2 Methods. Water levels were continuously monitored by the USGS at P-1, P-2 Upper and P-2 Lower, and by the WRSP at P-3. Float and time activated digital punch recorders were recording the level every hour at P-1, P-2 Upper, P-2 Lower, and P-3. For quality assurance, WRSP manually checked the water level at P-3 once per month.

Manual water level readings were taken by WRSP at G-8, G-8A, G-5, G-10, G-11, G-15, G-21, and P-4 in November 1977 and April 1978, which corresponded to the periods of minimum and maximum water levels, respectively, as found in the Baseline period.

4.1.2.3 Results to Date. The continuous hydrographs for wells P-1, P-2 Upper, P-2 Lower, and P-3 are shown in Figures 4-14 through 4-17. Seminannual static water level measurements for the other deep wells are shown in Table 4-12. The data indicate that the static water levels remained at levels similar to those found during the Baseline study at all wells, except at well P-3. The static water level of well P-3 continued to rise, as during the 1977 water year, until May 1978. From May through September the static water level remained relatively steady near 140.5 meters (461 feet) below the measuring point. In October 1976 at the beginning of the Interim period, the static water level of

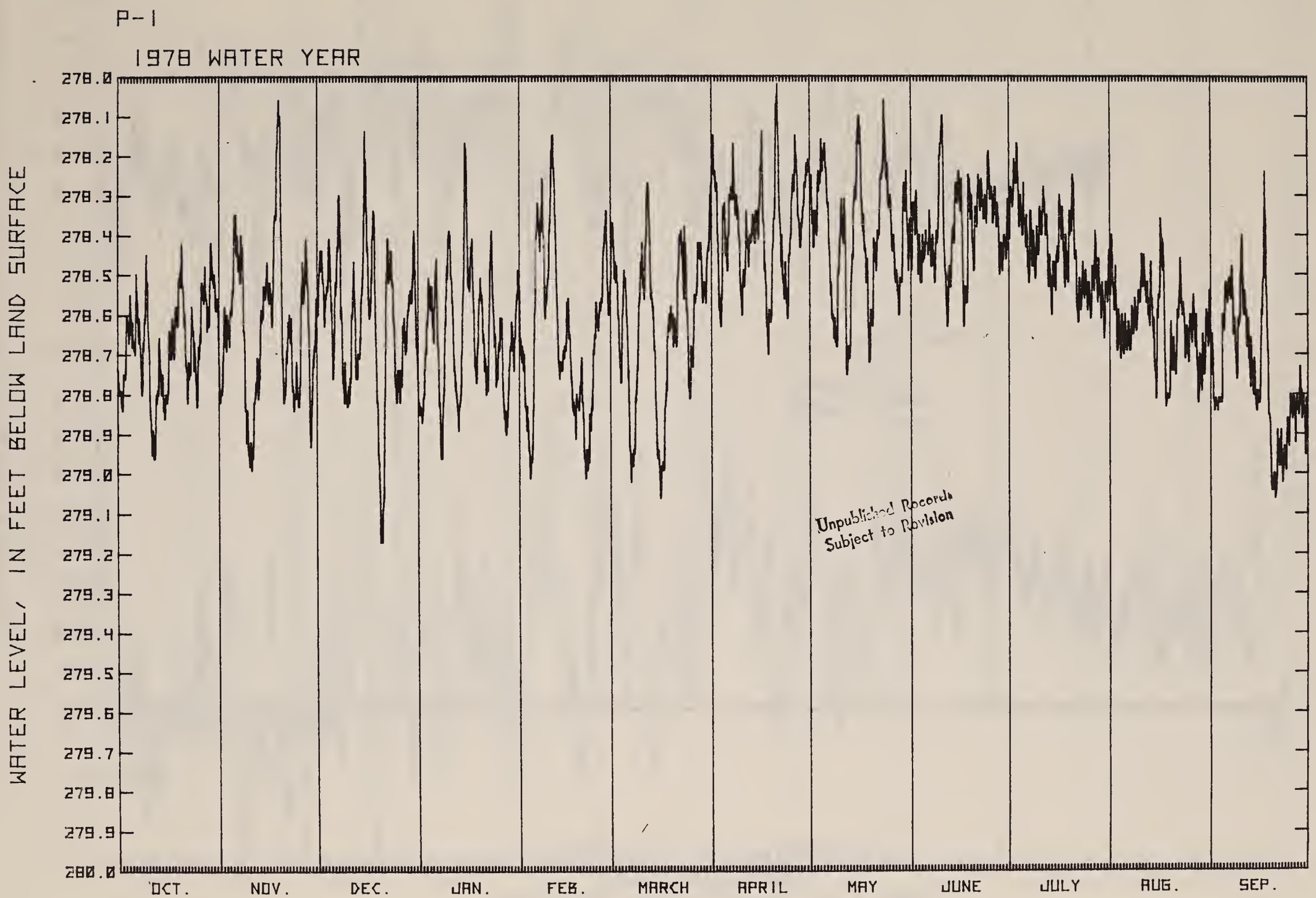
TABLE 4-11

RESPONSIBILITY FOR GROUND WATER MONITORING

Activity	Responsibility
Deep Aquifer Wells	
P-1, P-2 Upper, P-2 Lower: continuous monitoring of static water level.	USGS
P-3: continuous monitoring of static water level.	WRSP
G-8, G-8A, G-5, G-10, G-11, G-15, G-21, and P-4: semiannual static water level measurements.	WRSP
Alluvial Wells	
AG-1, AG-6: monthly measurements of static water level, temperature and specific conductance during February through October.	WRSP & USGS
AG-3, AG-8: quarterly measurements of static water level, temperature, and specific conductance.	USGS
AG-1, 3, 6, 8: semiannual water quality samples	WRSP & USGS

FIGURE 4-14

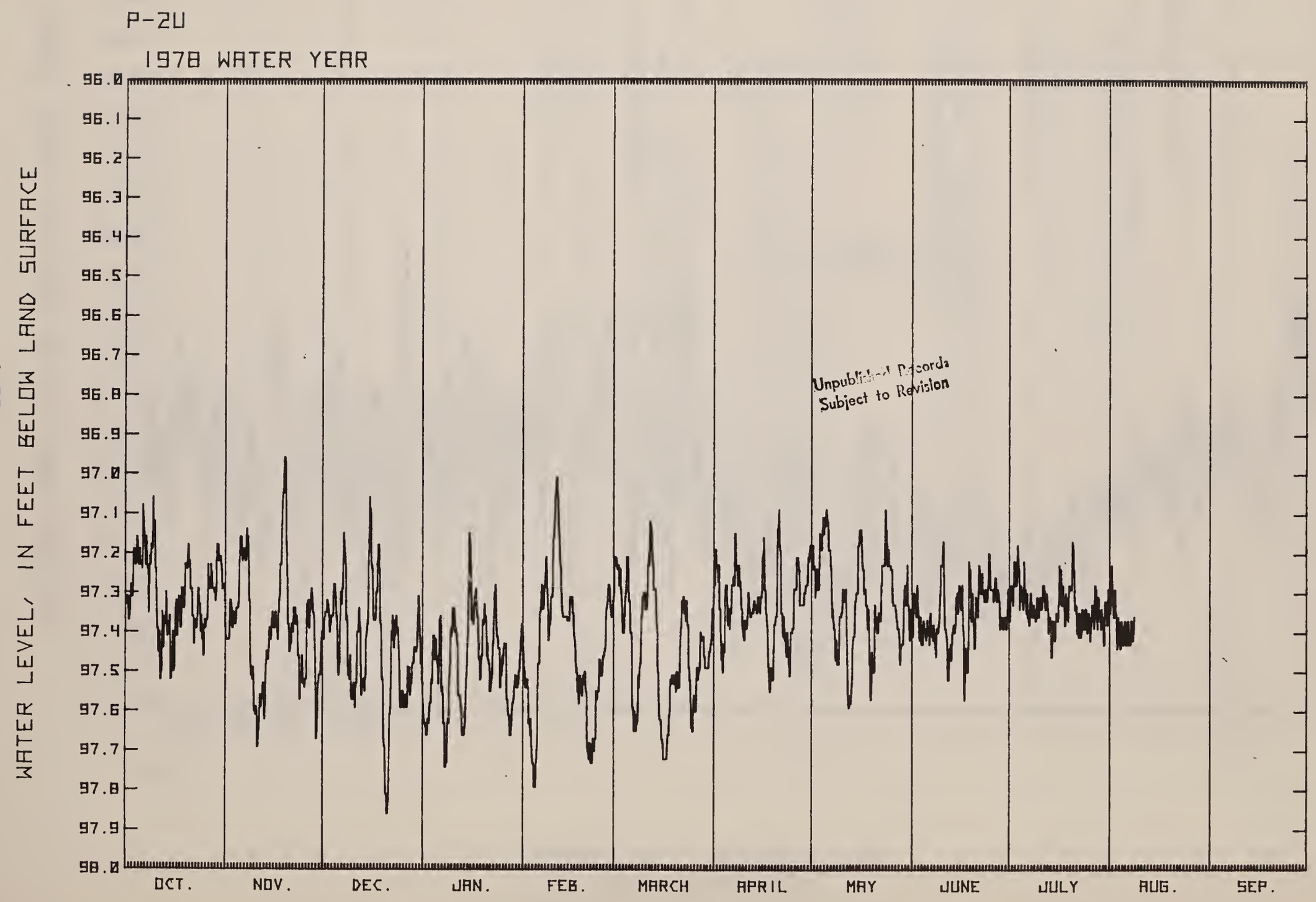
CONTINUOUS MONITORING WELL P-1
STATIC WATER LEVEL
OCTOBER 1977 - SEPTEMBER 1978



Note: Ground surface elevation = 5284
Measuring Point elevation = 5286.9

FIGURE 4-15

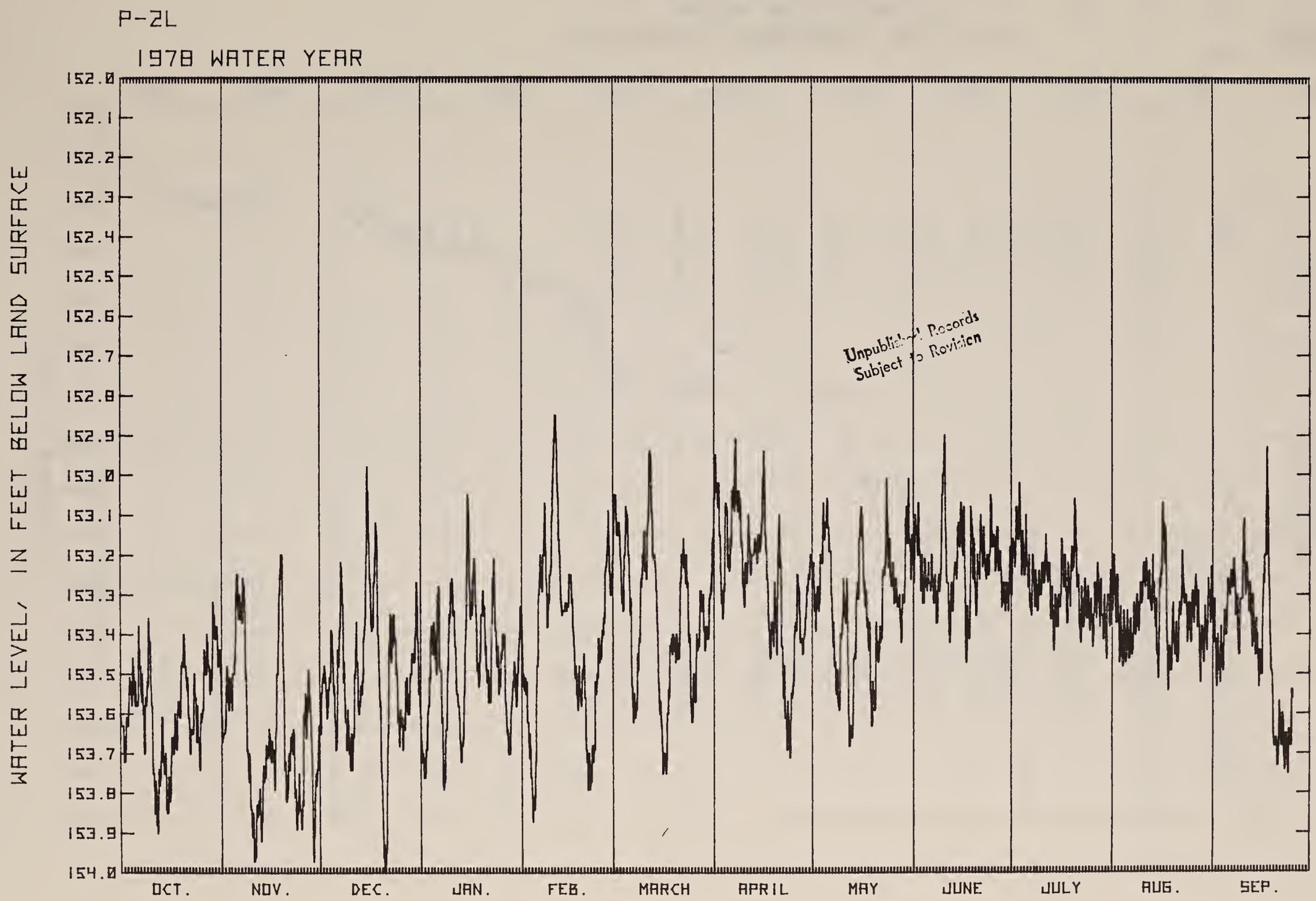
CONTINUOUS MONITORING WELL P-2 UPPER
STATIC WATER LEVEL
OCTOBER 1977 - SEPTEMBER 1978



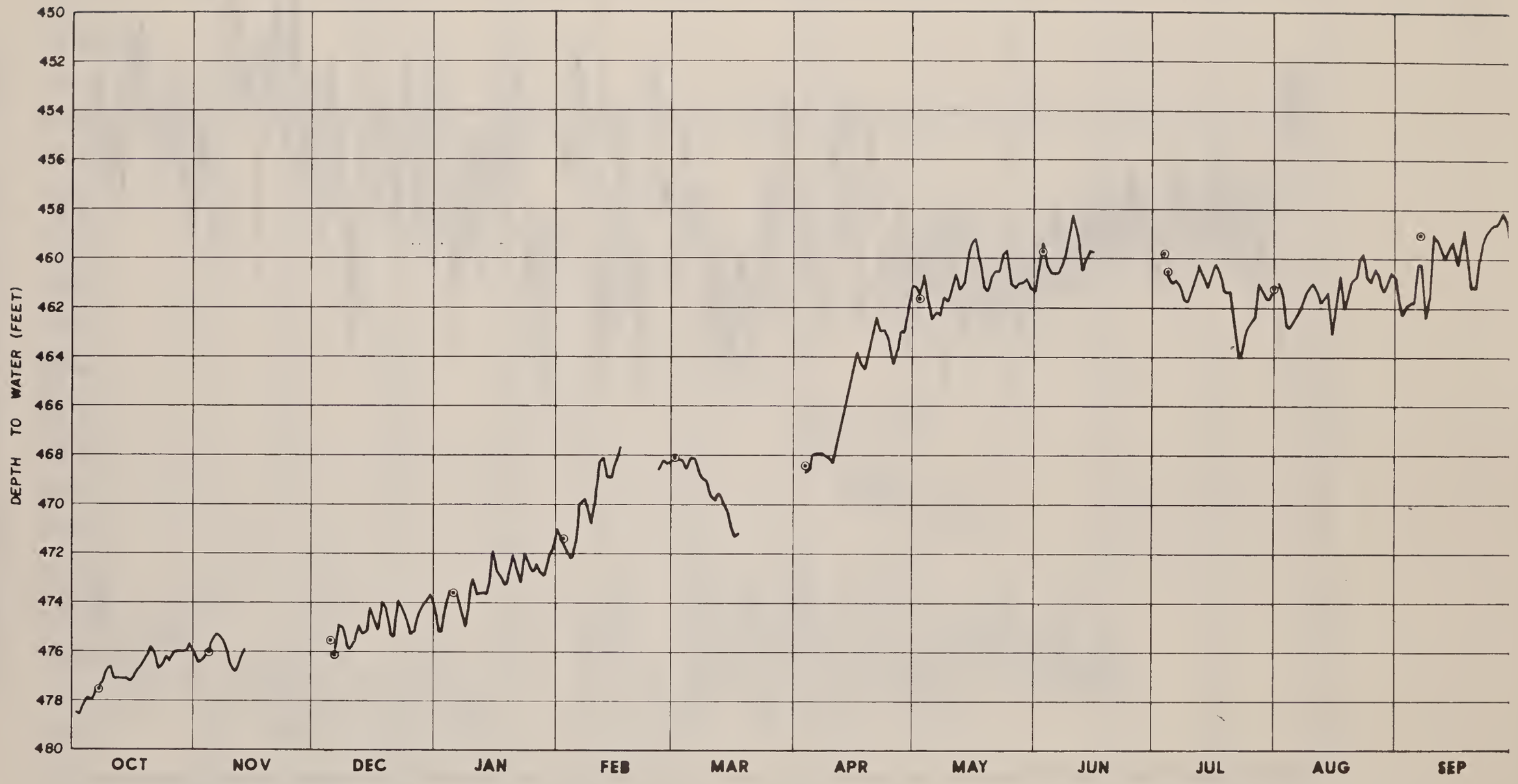
Note: Ground surface elevation = 4991
Measuring Point elevation = 4994.5

FIGURE 4-16

CONTINUOUS MONITORING WELL P-2 LOWER
STATIC WATER LEVEL
OCTOBER 1977 - SEPTEMBER 1978



Note: Ground Surface Elevation = 4990.5
Measuring Point elevation = 4993.3



CONTINUOUS MONITORING WELL P-3
STATIC WATER LEVEL
OCTOBER 1977 - SEPTEMBER 1978

NOTE: ⊙ ARE MANUAL MEASUREMENTS BY ELECTRIC PROBE.

FIGURE 4-17

TABLE 4-12

DEEP WELLS
SEMIANNUAL MEASUREMENTS
OCTOBER 1977 - SEPTEMBER 1978

WELL	DATE	DEPTH OF WATER (FT)
G-8	11-7-77	53.70
	4-13-78	53.34
G-8A	11-7-77	42.70
	4-13-78	41.54
G-5	11-7-77	459.60
	4-13-78	459.59
G-10	11-7-77	318.45
	4-13-78	311.60
G-11	11-7-77	469.20
	4-13-78	469.10
G-15	11-7-77	508.90
	4-13-78	508.85
G-21	11-7-77	429.75
	4-13-78	429.61
P-4	11-8-77	266.00
	4-13-78	265.68

well P-3 was 148.7 meters (488 feet) below the measuring point. This represents a rise in static water level of 8.2 meters (27 feet) in 22 months.

4.1.2.4 Conclusions. The static water levels of deep wells monitoring during the 1978 water year have remained steady at levels similar to those found during the Baseline study, with one exception at well P-3. Therefore, except for the P-3 location, the ground water surface in all three aquifers (Upper, Bird's Nest, and Douglas Creek) is remaining steady at similar levels as during the Baseline period. No explanation of the condition at well P-3 can be made at this time without further testing.

4.1.3 Alluvial Ground Water

The USGS Water Resources Division incorporated several WRSP wells into their own program after the Baseline period. The program discussed below, therefore, was carried out by the USGS, with supplemental efforts by WRSP. Table 4-13 presents a comparison of nomenclature for the alluvial wells. Table 4-11 presents the division of responsibilities of this program.

4.1.3.1 Objectives. The objectives of the program are to extend the data base in regard to alluvial well water levels and water quality, and to begin identifying long-term trends of these two parameters.

4.1.3.2 Methods. Monthly and quarterly measurements of static water level, temperature, and specific conductance were made at eight locations in five drainage areas:

1. White River (AG-1-1/2 and AG-3-1/2/3)
2. Evacuation Creek (near Park Canyon - 1/2, above Missouri Creek -1, and AG-8)

TABLE 4-13

COMPARISON OF NOMENCLATURE

ALLUVIAL WELLS

WRSP Nomenclature	USGS Nomenclature	Nomenclature for Report
AG-1 Lower	AG-1 #1	AG-1-1
AG-1 Upper	AG-1 #2	AG-1-2
AG-3 Lower (USGS)	White River Alluvium #1	AG-3-1
AG-3 Upper (USGS)	White River Alluvium #2	AG-3-2
AG-3 Upper (WRSP)	White River Alluvium #3	AG-3-3
AG-4	AG-4	AG-4
AG-6 Lower	Southam Canyon #1	AG-6-1
AG-6 Upper	Southam Canyon #2	AG-6-2
AG-8	AG-8	AG-8
Evacuation Creek Near Park Canyon, Lower	Evacuation Creek Near Park Canyon #1	Evacuation Creek Near Park Canyon -1
Evacuation Creek Near Park Canyon, Upper	Evacuation Creek Near Park Canyon #2	Evacuation Creek Near Park Canyon -2
Evacuation Creek Above Missouri Creek, Lower	Evacuation Creek Above Missouri Creek #1	Evacuation Creek Above Missouri Creek -1
Hell's Hole Canyon, Lower	Hell's Hole Canyon #1	Hell's Hole Canyon -1
Hell's Hole Canyon, Upper	Hell's Hole Canyon #2	Hell's Hole Canyon -2

3. Asphalt Wash (AG-4)

4. Southam Canyon (AG-6-1/2)

5. Hell's Hole Canyon (near mouth - 1/2)

According to the December 1976 Work Plan for the Interim period, water quality samples were to be collected semiannually (during high and low flow periods) at the AG-1, AG-3, AG-6 and AG-8 locations during the 1978 water year. However, based on the first two years of record, personnel from USGS - Water Resources Division (Salt Lake City) decided in March, 1978 to follow a revised program. The new USGS program required that water quality samples be collected from these wells only when the specific conductance measurement at the well was 10% greater than the maximum value or 10% less than the minimum value from the period of record for that well. Based on this criteria, the USGS collected samples from wells AG-6-1 and AG-6-2 on May 26, 1978. No samples were collected from the wells at the AG-1, AG-3, and AG-8 locations since the specific conductance measurements satisfied the USGS criteria.

The water quality data during the first two wells of record for the alluvial wells indicated that the water quality was remaining relatively stable for all of the wells, except for the wells at the AG-6 location. Because of this situation, WRSP and VTN agreed with the USGS revision to the alluvial well program, and did not collect additional water quality samples.

4.1.3.3 Results to Date.

Static Water Levels

The measurements of static water level of the alluvial wells during the 1978 water year are shown in Tables 4-14 through 4-16.

TABLE 4-14

ALLUVIAL WELL MEASUREMENTS
WHITE RIVER ALLUVIUM
OCTOBER 1977 - SEPTEMBER 1978

		Oct	Nov	Dec	Jan	Feb	Mar		Apr	May	Jun		Jul	Aug	Sep
AG-1-1															
	Date		13*	20*		2*	15*	16		17*	13	15*		22*	22*
	SWL		14.00	13.95		13.00	13.65	13.46		12.18	11.01	11.05		13.68	13.65
	T		12.0	8.5		7.0	9.0	- -		4.0	10.5	9.0		16.2	12.5
	SC		875	950		950	980	- -		1000	880	1175		850	1060
AG-1-2															
	Date		13*	20*		2*	15*	16		17*	13	15*		22*	22*
	SWL		13.85	13.80		12.90	13.67	13.57		12.20	11.10	11.07		13.83	13.50
	T		12.5	7.5		6.5	9.0	- -		4.5	10.5	7.5		17.0	13.5
	SC		850	925		850	900	- -		1450	910	1100		860	980
AG-3-1															
	Date	18				15	16						13		
	SWL	12.77				12.49	12.17						11.13		
	T	13.0				10.5	- -						- -		
	SC	4220				4550	- -						- -		
AG-3-2															
	Date	18				15	16						13		
	SWL	12.02				11.69	11.65						10.59		
	T	13.0				10.5	- -						- -		
	SC	2500				2600	- -						- -		
AG-3-3															
	Date	18				15	16						13		
	SWL	12.45				12.16	12.17						11.13		
	T	12.0				9.5	- -						- -		
	SC	3550				3600	- -						- -		

Note: Static water level (SWL) is in feet; temperature (T) is in ^{o}C; specific conductance (SC) is in micromhos/cm.

* Note: Measurements were taken by WRSP.

TABLE 4-15

ALLUVIAL WELL MEASUREMENTS
EVACUATION CREEK ALLUVIUM
OCTOBER 1977 - SEPTEMBER 1978

		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
AG-8													
	Date	13		7		28	16		26				
	SWL	4.51		4.32		Frozen	4.22		4.29				
	T	13.0		- -			7.0		11.0				
	SC	4430		- -			3300		4600				
Evac Cr Near Park Canyon-1													
	Date	12		7		28	24			14			
	SWL	15.67		15.05		14.16	14.10			14.86			
	T	10.5		- -		9.0	- -			10.0			
	SC	4200		- -		4120	- -			4300			
Evac Cr Near Park Canyon-2													
	Date	12		7		28	24			14			
	SWL	14.53		13.97		12.90	12.80			13.74			
	T	11.0		- -		8.5	- -			9.0			
	SC	4520		- -		4550	- -			4550			
Evac Cr Above Missouri Creek-1													
	Date	12				28	24			14			
	SWL	28.40				27.34	27.58			28.28			
	T	10.5				10.5	- -			11.5			
	SC	4200				4080	- -			4300			

Note: Static water level (SWL) is in feet; temperature (T) is in ^{o}C; specific conductance (SC) is in micromhos/cm.

TABLE 4-16

ALLUVIAL WELL MEASUREMENTS
DRY WASHES ALLUVIUM
OCTOBER 1977 - SEPTEMBER 1978

		Oct	Nov	Dec	Jan	Feb	Mar		Apr	May		Jun	Jul	Aug	Sep
AG-4															
	Date	18				15	16						13		
	SWL	30.90				30.36	30.33						28.39		
	T	13.0				12.5	- -						- -		
	SC	1330				1400	- -						- -		
AG-6-1															
	Date	18	15*	19*	30*	22	13*	16		17*	26	15*		25*	22*
	SWL	18.05	18.00	18.10	17.65	17.52	17.65	17.55		16.96	16.07	15.50		17.86	17.85
	T	12.5	15.0	11.5	12.5	12.0	12.0	12.0		6.0	12.0	9.5		17.0	17.5
	SC	4300	2800	2500	2800	2900	2150	2320		2200	2170	1700		1650	1750
AG-6-2															
	Date	18	13*	19*	30*	22	13*	16		17*	26	15*		25*	22*
	SWL	19.33	19.50	19.20	18.95	18.80	18.95	18.83		18.38	17.36	16.95		19.00	19.00
	T	13.0	14.0	10.5	11.5	12.5	12.0	12.5		6.5	12.5	9.5		16.0	15.5
	SC	1850	1800	1600	1750	1680	1750	1480		1950	1650	1900		1375	1300
Hell's Hole Canyon-1															
	Date	12					3	24				13			
	SWL	17.84					17.46	16.26				17.38			
	T	12.0					11.0	- -				12.5			
	SC	2300					2100	- -				2170			
Hell's Hole Canyon-2															
	Date	12					3	24				13			
	SWL	17.25					16.88	15.56				16.73			
	T	12.0					11.5	- -				12.5			
	SC	2570					2250	- -				2370			

Note: Static water level (SWL) is in feet; temperature (T) is in °C; specific conductance (SC) is in micromhos/cm.

* Note: Measurements were taken by WRSP.

White River Alluvium: The ranges of static water level at the AG-1 and AG-3 locations were similar to the ranges during the Baseline period. Water levels were highest during the runoff period and lowest during the baseflow period of the White River. Water level fluctuations were about 0.88 meter (2.9 feet) at the AG-1 location and were about 0.45 meter (1.5 feet) at the AG-3 location. The upper and lower wells followed similar fluctuations at each location.

Evacuation Creek Alluvium: The ranges of static water level for the locations at AG-8, near Park Canyon, and above Missouri Creek were similar to the ranges during the Baseline period. Water levels were highest during February and March and lowest during October. The water level fluctuations were 0.09 meter (0.3 feet) at AG-8, 0.50 meter (1.65 feet) near Park Canyon, and 0.24 meter (0.8 feet) above Missouri Creek. The upper and lower wells near Park Canyon followed similar fluctuations.

Dry Washes Alluvium: The ranges of static water level at the AG-4, AG-6, and Hell's Hole Canyon locations were similar to the ranges during the Baseline period. At the AG-4 and AG-6 locations the water levels were highest during June and July and lowest during October, November and December. At the Hell's Hole Canyon location, water levels were highest during March and lowest during October. Water level fluctuations were 0.80 meter (2.61 feet) at AG-4, 0.78 meter (2.55 feet) at the AG-6 location, and 0.50 meter (1.64 feet) at the Hell's Hole Canyon location. The upper and lower wells followed similar fluctuations at the AG-6 and Hell's Hole Canyon locations.

Alluvial Water Quality

The measurements of temperature and specific conductance of

the alluvial wells during the 1978 water year are shown in Tables 4-14 through 4-16.

White River Alluvium: Several of the values of specific conductance at well AG-1-2 are considerably below the minimum during the first two years of record (1300 micromhos/cm). In the past it has been extremely difficult to obtain a sample from this well because it recharges very slowly. Therefore, no water quality samples were collected from this well during the 1978 water year.

The values of specific conductance at well AG-1-1 and wells AG-3-1, 2, 3 were similar to values during the first two years of record. This indicates that the water quality at these wells has been remaining stable in comparison to the Baseline period. The aspects of water quality during the first two years of record for all of the alluvial wells were described in detail in the 1977 Interim period annual report and the 1977 supplemental report, as well as in the Final Environmental Baseline Report (FEBR).

Evacuation Creek Alluvium: The values of specific conductance at well AG-8, and the wells near Park Canyon and above Missouri Creek were similar to the values during the first two years of record. This indicates that the water quality at these wells is remaining stable in comparison to the Baseline period.

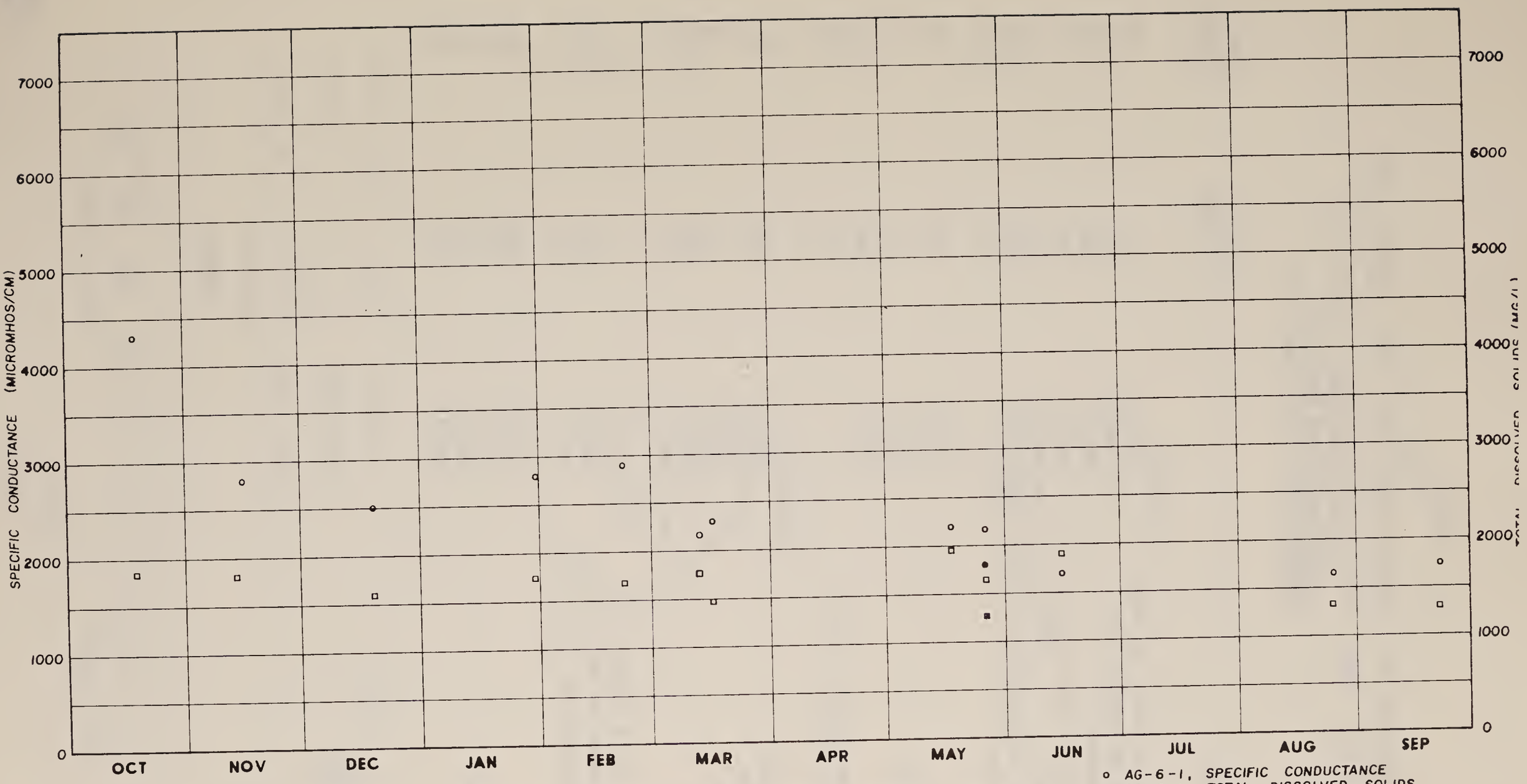
Dry Washes Alluvium: The values of specific conductance at well AG-4, and the wells at the Hell's Hole Canyon location were similar to values during the first two years of record. Again, this indicates that the water quality has been remaining stable in comparison to the Baseline period.

The water quality of the wells at the AG-6 location have not remained steady throughout the period of record, but the trend of the values of specific conductance during the 1978 water year did level out. This trend is illustrated in Figure 4-18. The water quality analyses from samples collected from these two wells on May 26, 1978 are shown in Table 4-17. The lower well, AG-6-1, in general has had higher specific conductance and total dissolved solids values than the upper well, AG-6-2, during the period of record. However, the differences of these values between the two wells have been steadily decreasing in time. Figure 4-19 illustrates the most recent comparison of the balance and distribution of major ions for these two wells. Calcium, magnesium, sodium, and sulfate concentrations are considerably different, while potassium, chloride, and bicarbonate are relatively similar.

4.1.3.4 Conclusions.

Comparison of Water Level and Chemical Compositon Between Baseline Period and 1978 Water Year

The static water levels of all of the alluvial wells involved in the program were similar to levels during the Baseline period. The chemical composition, as indicated by the measurements of specific conductance, was similar to values during the Baseline period, except at wells AG-1-2, AG-6-1, and AG-6-2. Specific conductance values at well AG-1-2 were lower than during the Baseline period, but no water quality sample was collected due to difficulties in obtaining enough water from this well. The specific conductance values and water quality samples from wells AG-6-1 and AG-6-2 indicate that the concentrations of total dissolved solids has been decreasing steadily in time, but appears to have leveled off during the 1978 water year. This



VARIATION IN TIME OF SPECIFIC CONDUCTANCE AND TOTAL DISSOLVED SOLIDS
ALLUVIAL WELLS AG-6-1 AND AG-6-2
OCTOBER 1977 — SEPTEMBER 1978

FIGURE 4-18

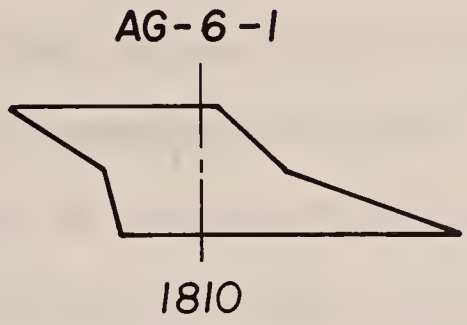
TABLE 4-17

ALLUVIAL WELLS
WATER QUALITY ANALYSES
OCTOBER 1977 - SEPTEMBER 1978

Parameters		AG-6-1 5-26-78	AG-6-2 5-26-78
Total Alkalinity as $CaCO_3$	(mg/l)	320	320
Total Dissolved Solids	(mg/l)	1810	1250
Total Hardness	(mg/l)	680	310
Noncarbonate Hardness	(mg/l)	360	0
pH, field	(units)	7.6	7.7
Specific Conductance, field	(umhos/cm)	2170	1650
Temperature	(Deg. C)	12.0	12.5
Calcium	(mg/l)	150	95
Magnesium	(mg/l)	75	18
Potassium	(mg/l)	3.5	3.3
Sodium	(mg/l)	340	280
Sodium Adsorption Ratio		5.7	6.9
Percent Sodium		52	66
Bicarbonate	(mg/l)	390	390
Carbonate	(mg/l)	0	0
Chloride	(mg/l)	48	38
Sulfate	(mg/l)	970	600
Fluoride	(mg/l)	0.3	0.2
Nitrite and Nitrate as N	(mg/l)	2.1	0.25
Orthophosphorus as P, diss.	(mg/l)	0.32	0.03
Orthophosphate as PO_4, diss.	(mg/l)	0.98	0.09
Boron	(ug/l)	270	260
Iron	(ug/l)	10	20
Manganese	(ug/l)	600	380
Silica	(mg/l)	19	19

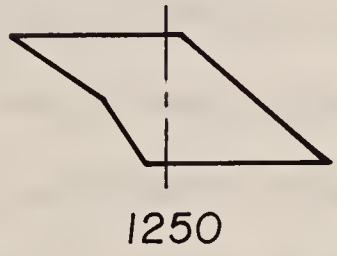
FIGURE 4-19

BALANCE AND DISTRIBUTIONS OF MAJOR IONS ALLUVIAL WATER QUALITY - DRY WASHES MAY 26, 1978



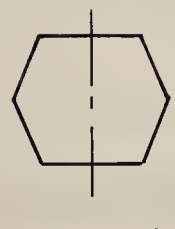
-0.8 %

AG-6-2



+3.9 %

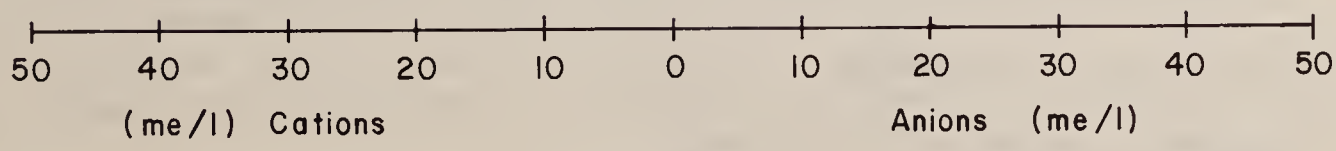
(me/l) Na + K
(me/l) Ca
(me/l) Mg



Cl (me/l)
HCO_3 (me/l)
SO_4 (me/l)

0.0 % = Percent By Which Anions Exceed Cations

Legend



Scale

trend has been discussed in previous reports, and apparently is due to the decreasing effect in time of the upstream discharges from the P-2 wells during the initial portion of the Baseline period.

Comparison of Water Level and Chemical Composition Between AG-1 and AG-3

The fluctuation of static water level with respect to time was similar at the AG-1 and AG-3 locations during the 1978 water year. However, the water level fluctuation at AG-1 was about 0.88 meter (2.9 feet), while at AG-3 the fluctuation was about 0.45 meter (1.5 feet). Possible causes for this situation were discussed in the 1977 annual report for the Interim period.

These two locations have exhibited considerable differences in chemical composition of the alluvial water during the previous years of record. In general, the specific conductance and the concentration of total dissolved solids was higher at the AG-3 location than at the AG-1 location. Also, there were differences in the distribution of the major ions. During 1978, the vaules of specific conductance for wells AG-1-1 and AG-3-1, 2, and 3 were similar to comparable values during the previous years. Therefore, the comparison of chemical composition at the AG-1 and AG-3 locations described in the 1977 annual report and the 1977 supplemental report should still describe the situation during the 1978 water year.

Comparison of Water Level and Chemical Composition Between Upper and Lower Wells

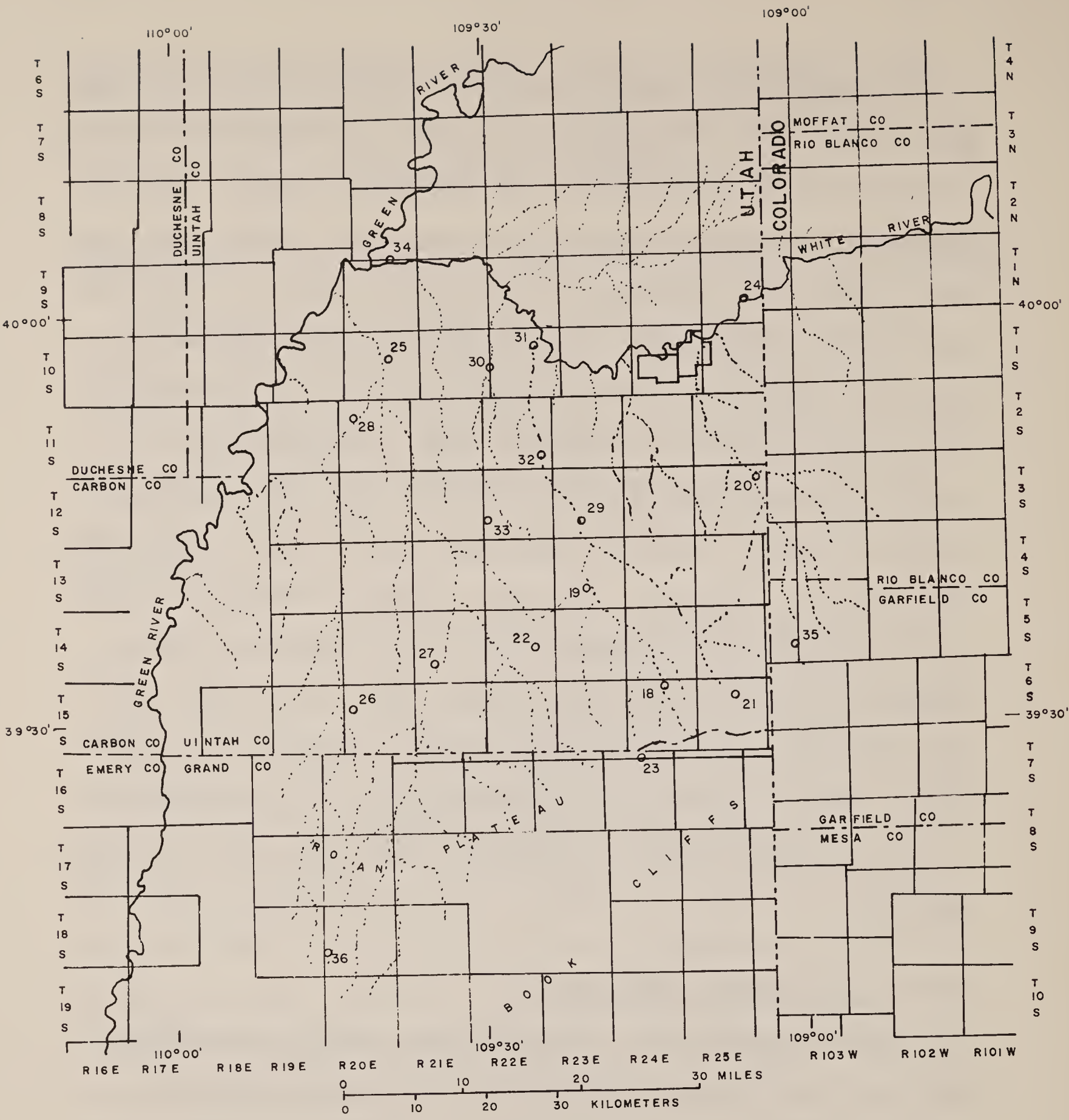
The static water levels of upper and lower wells at each location have shown similar ranges of fluctuation and similar variation in time throughout the period of record.

The comparison of chemical composition between the upper and lower wells at AG-1, AG-3, and Evacuation Creek near Park Canyon was described in the 1977 annual report and the 1977 supplemental report. Since the measurements of specific conductance at these wells indicate that there were no significant differences in water quality between the 1978 water year and the previous years of record, that description should still be adequate. However, the chemical composition of the alluvial water at the AG-6 location has been changing in time. The measurements of specific conductance during 1978 indicate that the water quality has become more stable. The most recent water quality sample analyses from these two wells (collected in May 1978) are shown in Table 4-17. The specific conductance and concentration of total dissolved solids are somewhat higher for the lower well, AG-6-1, than for the upper well, AG-6-2 (2170 vs. 1650 micromhos/cm and 1810 vs. 1250 mg/l, respectively). This is due mostly to considerably higher concentrations of calcium, magnesium, sodium, and sulfate for the lower well than for the upper well.

4.1.4 Precipitation/Evaporation

The following program is a combination of efforts by the USGS and WRSP. The USGS Water Resources Division has been monitoring a regional network of precipitation gages in the Uinta basin in the vicinity of Tracts Ua/Ub. WRSP monitors a site specific network of precipitation gages and evaporation pans located on the tracts.

4.1.4.1 Objectives. The objectives of the precipitation/evaporation program are to augment the USGS regional data collection network, shown in Figure 4-20, to provide site specific information on precipitation and evaporation at the plant site and processed shale



LEGEND

10
o
Precipitation gage
File Number

USGS REGIONAL PRECIPITATION NETWORK

FIGURE 4-20

disposal area, and to place the Interim period in historic perspective.

4.1.4.2 Methods. Precipitation was measured by automatic gages at three locations. The gage at the plant site (ARA-13) was operated year round. The other two automatic gages in Southam Canyon (ARA-2 and ARS-9) were in operation from April 1, 1978 through September 30, 1978. Precipitation was measured by standard storage gages at the three automatic gage locations (as a back up in case of breakdowns) as well as at the mouth of Southam Canyon (RS-13) and at the A-4 air station located between Southam Canyon and Evacuation Creek (RA-4). These two gages were monitored from April through September. Also, the annual precipitation records from two storage gages involved in the revegetation study for Tracts Ua/Ub were obtained. These gages are located near the A-7 air station north of the White River (RV-7) and near well G-8 in the Evacuation Creek drainage (RV-8).

Evaporation from ground pans was measured in Southam Canyon (EVP-2) and at the plant site (EVP-13) during the freeze-free period. The records for these two sites began May 6 and May 5, respectively, and ended on September 19, 1978.

4.1.4.3 Results to Date.

Precipitation

Monthly, seasonal, and annual precipitation data for the WRSP gages are shown in Table 4-18. The spatial variations of annual and seasonal precipitation on the tracts are shown in Figures 4-21 through 4-25. Annual precipitation varied from a maximum of 20.57 cm (8.10 inches) at RV-7 to a minimum of 16.21 cm (6.38 inches) at RV-8. Fall precipitation (October, November, December) does not show a clear trend, which is due

TABLE 4-18

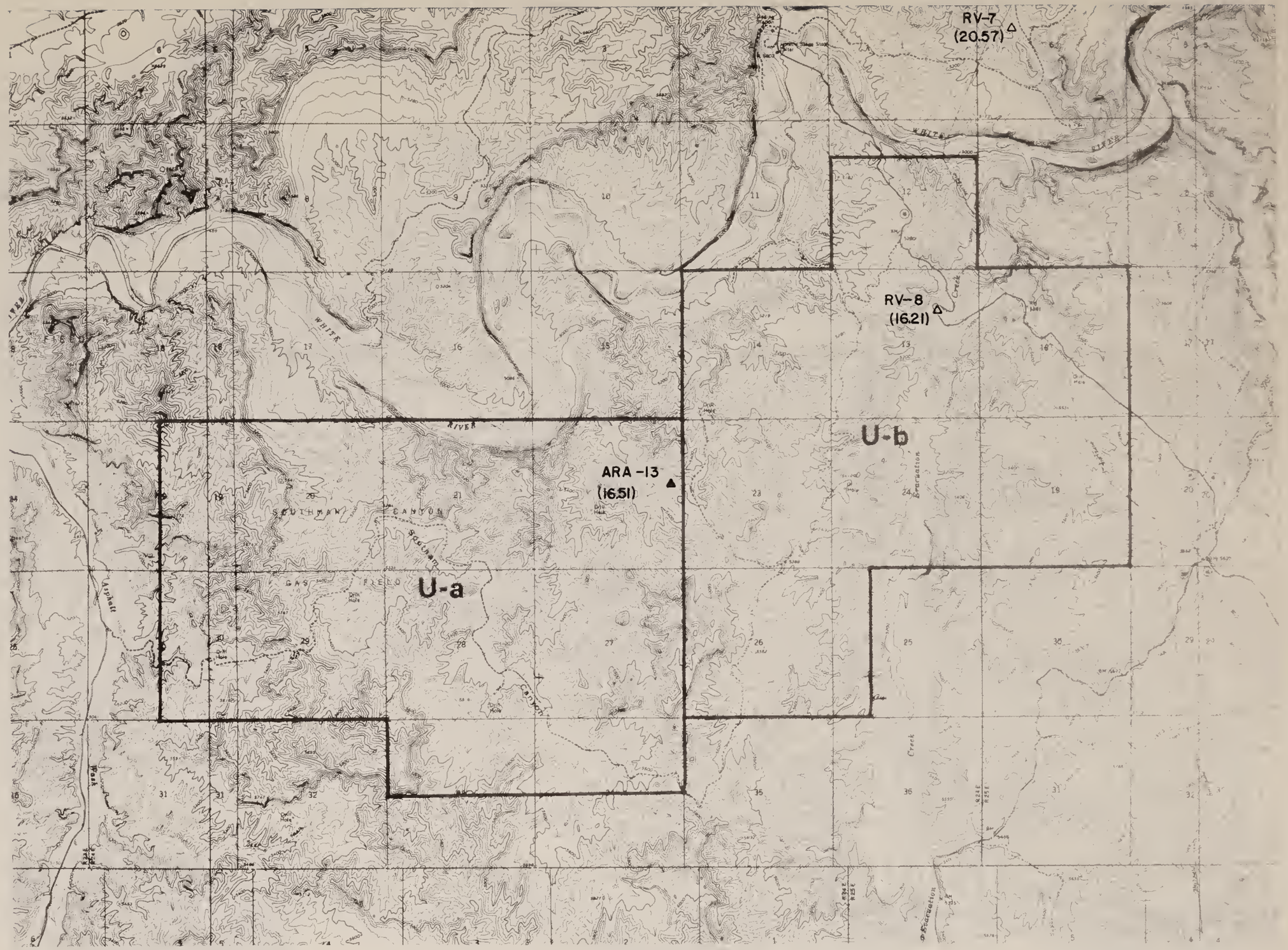
PRECIPITATION RECORDS
OCTOBER 1977 - SEPTEMBER 1978

STATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT-DEC	JAN-MAR	APR-JUN	JUL-SEP	ANNUAL
ARA-2	0.85	- -	- -	- -	- -	- -	0.60	0.30	0.30	0.10	0.60	0.10	- -	- -	1.20 in (3.05 cm)	0.80 in (2.03 cm)	- -
RA-4	- -	- -	- -	- -	- -	- -	1.0 E	0.20	0.08	0.12	0.46	0.31	- -	- -	1.28 in (3.25 cm)	0.89 in (2.26 cm)	- -
ARS-9	1.02*	- -	- -	- -	- -	- -	1.20	0.30	T	0.10	0.40	0.20	- -	- -	1.50 in (3.81 cm)	0.70 in (1.78 cm)	- -
ARA-13	0.90	0.90	0.30	1.20	0.20	1.10	0.90	0.20	0.10	0.00	0.40	0.30	2.10 in (5.33 cm)	2.50 in (6.35 cm)	1.20 in (3.05 cm)	0.70 in (1.78 cm)	6.50 in (16.51 cm)
RS-13	0.98	- -	- -	- -	- -	- -	1.55	0.13	0.10	T	0.52	0.35	- -	- -	1.78 in (4.52 cm)	0.77 in (1.96 cm)	- -
RV-7	0.63	1.35	1.30	1.37	0.40	0.40	1.46	0.32	T	0.00	0.46	0.41	3.28 in (8.33 cm)	2.17 in (5.51 cm)	1.78 in (4.52 cm)	0.87 in (2.21 cm)	8.10 in (20.57 cm)
RV-8	1.14	1.35	0.20	1.5 E	0.38	0.30	0.50	0.15	T	0.05	0.45	0.36	2.69 in (6.83 cm)	2.18 in (5.54 in)	0.65 in (1.65 cm)	0.86 in (2.18 cm)	6.38 in (16.21 cm)

Note: The designation, E, means that part of the record was estimated.

*from backup gage

ANNUAL PRECIPITATION
IN CENTIMETERS
OCT 1977 – SEP 1978



LEGEND

▲ PRECIPITATION (AUTOMATIC)

△ PRECIPITATION (STORAGE)

UTAH

N

1 0 1
SCALE IN MILES

FIGURE 4- 21

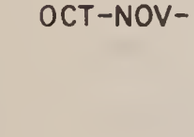
FALL PRECIPITATION IN CENTIMETERS

OCT-NOV-DEC 1977

LEGEND

▲ PRECIPITATION (AUTOMATIC)

△ PRECIPITATION (STORAGE)



1 0 1

SCALE IN MILES

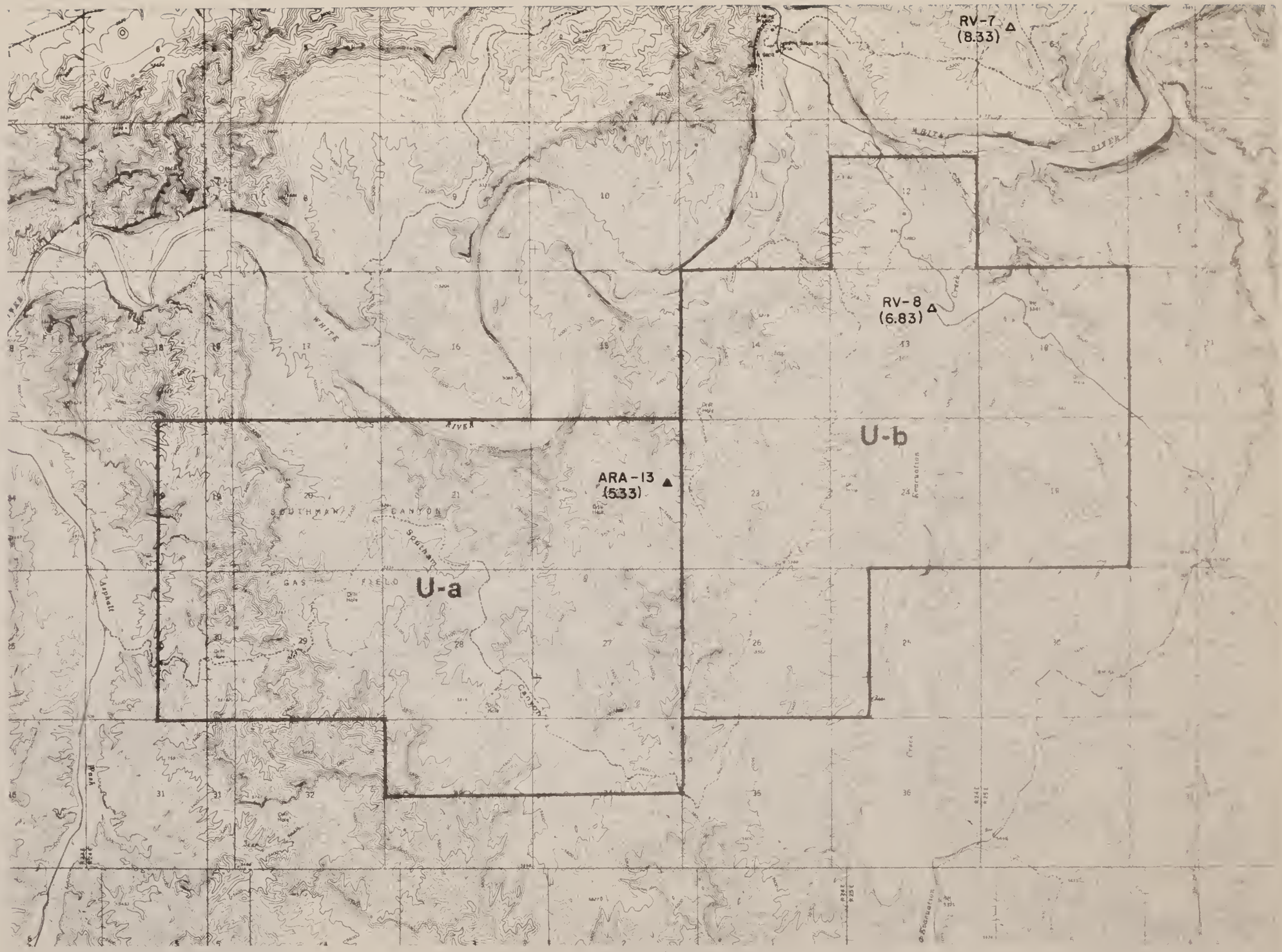
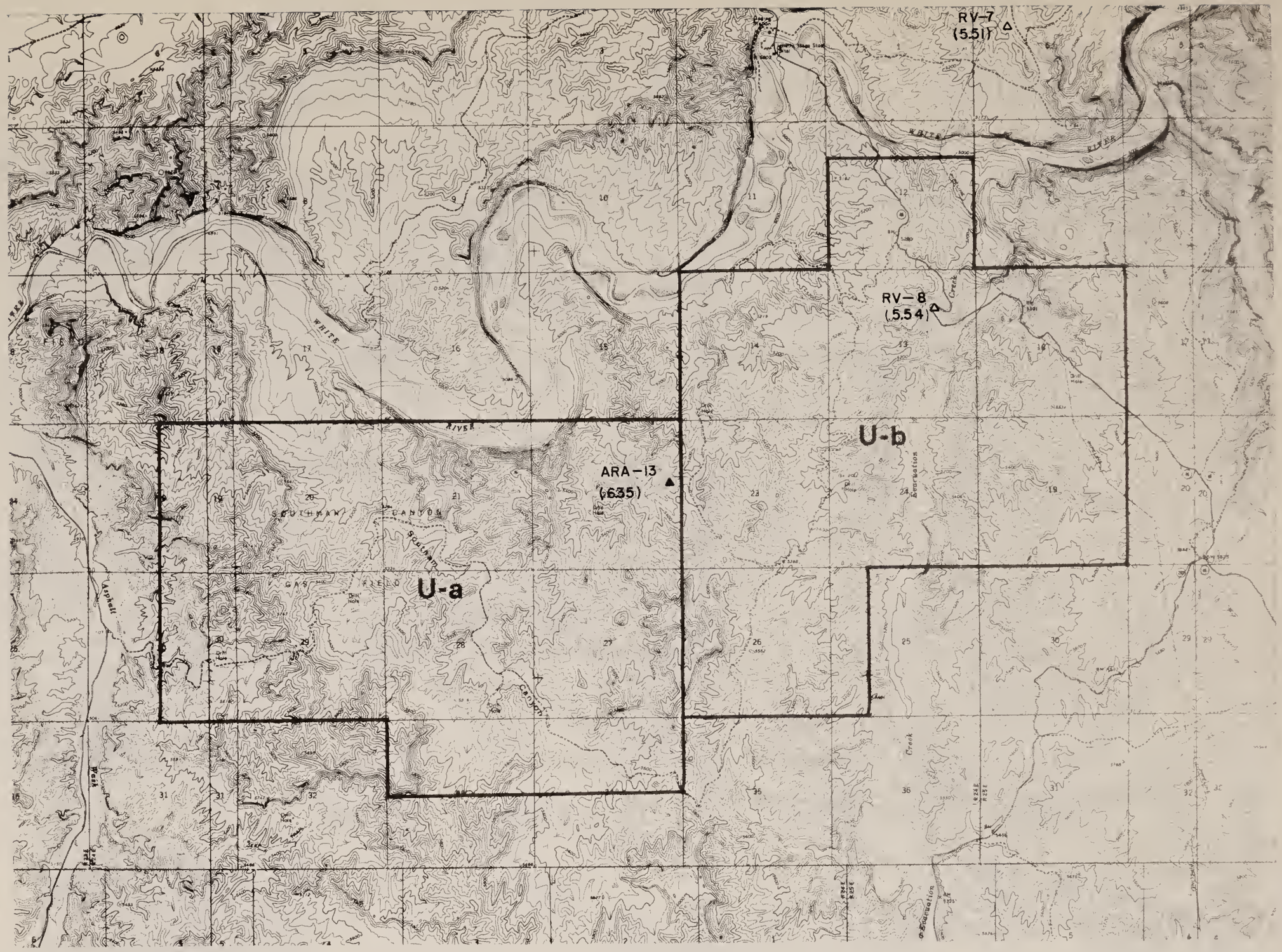


FIGURE 4-22

WINTER PRECIPITATION IN CENTIMETERS
JAN - FEB - MAR 1978



LEGEND

▲ PRECIPITATION (AUTOMATIC)

△ PRECIPITATION (STORAGE)

1 0 1
SCALE IN MILES

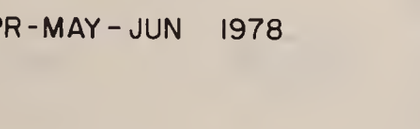
FIGURE 4-23

SPRING PRECIPITATION IN CENTIMETERS

APR - MAY - JUN 1978

LEGEND

- ▲ PRECIPITATION (AUTOMATIC)
- △ PRECIPITATION (STORAGE)
- —— PRECIPITATION ISOHYETAL
- – – PRECIPITATION ISOHYETAL (ESTIMATED)



1 0 1

SCALE IN MILES

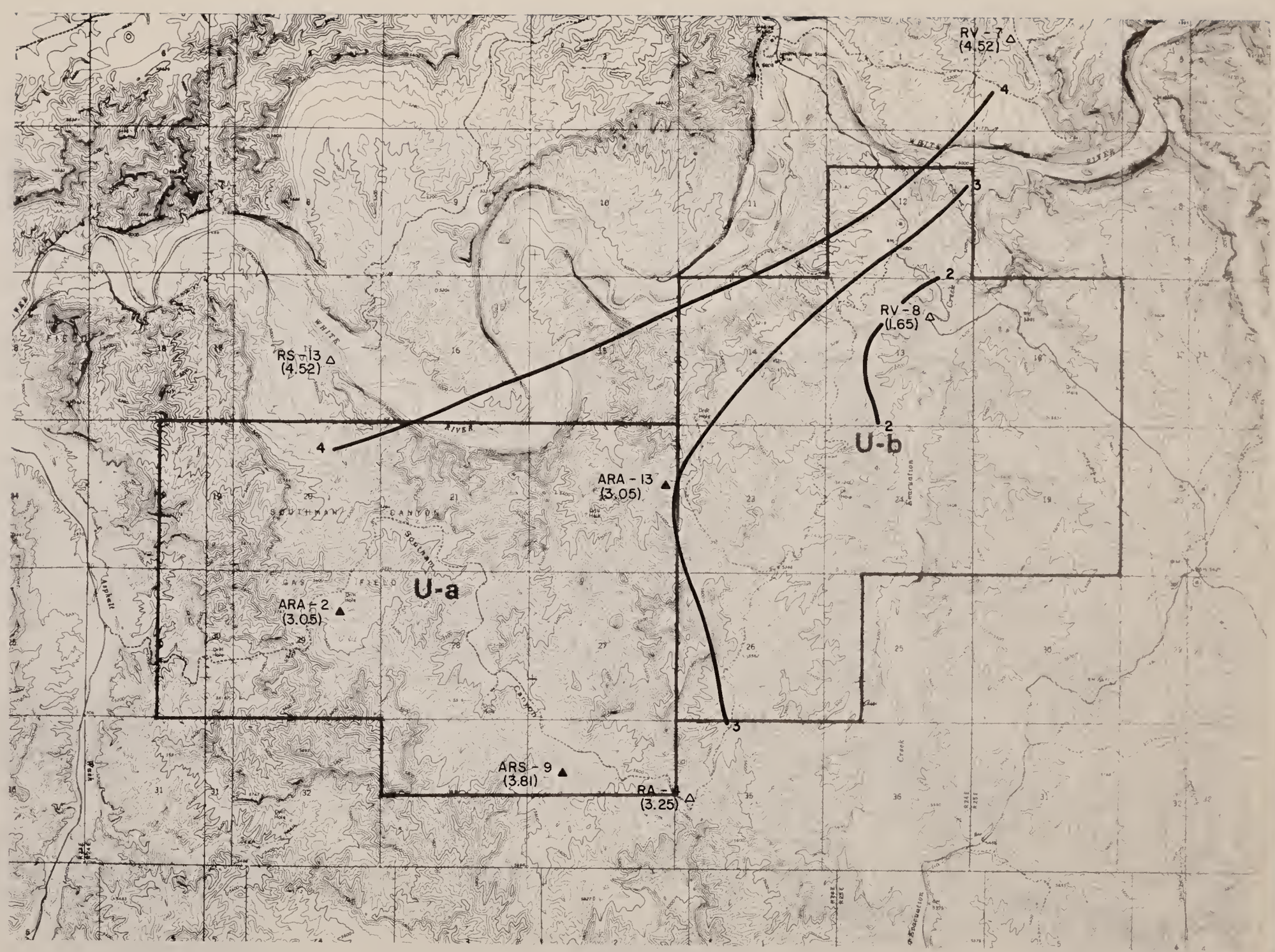
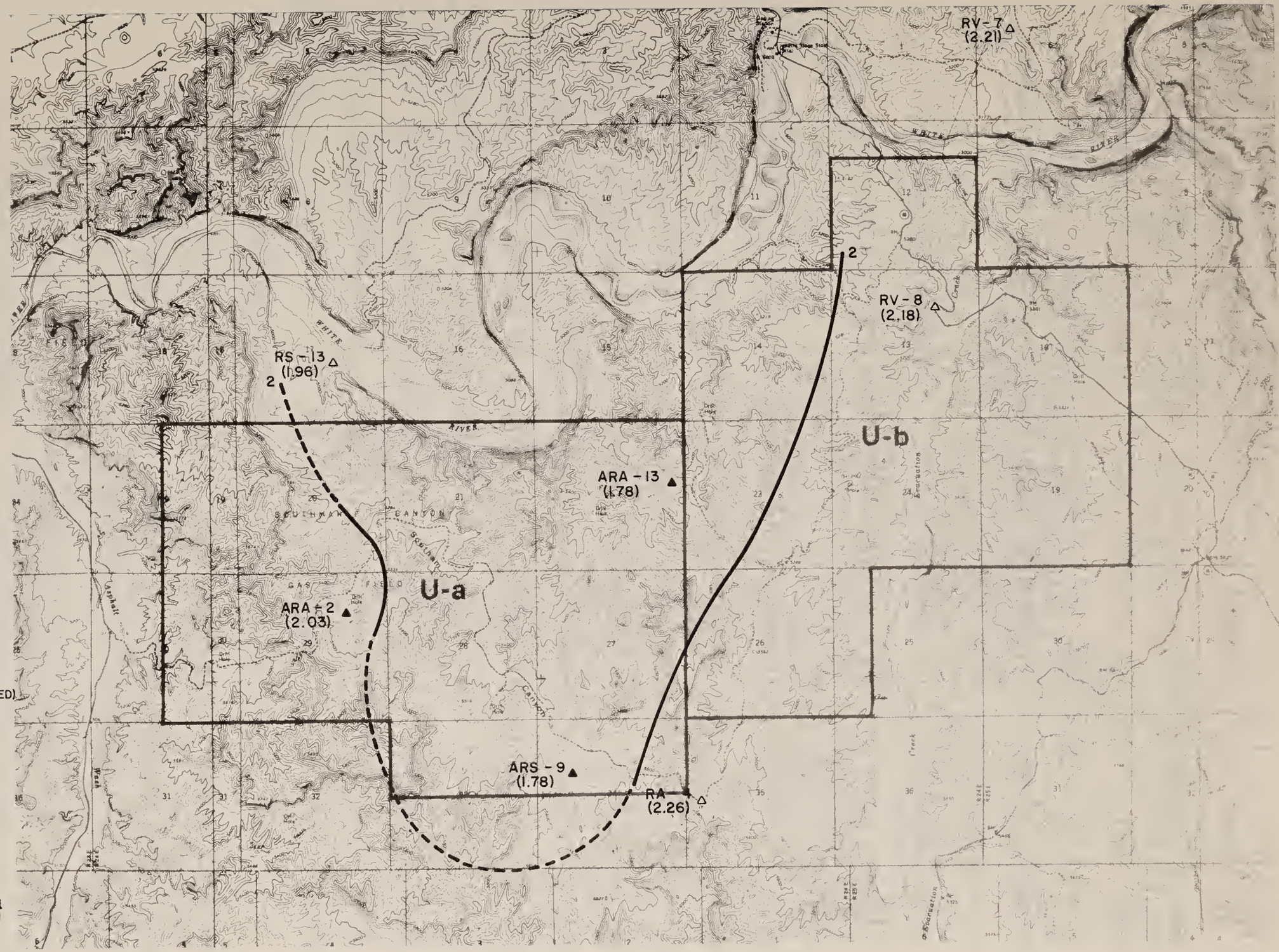


FIGURE 4-24

SUMMER PRECIPITATION
IN CENTIMETERS

JUL-AUG-SEP 1978



LEGEND

- ▲ PRECIPITATION (AUTOMATIC)
- △ PRECIPITATION (STORAGE)
- —— PRECIPITATION ISOHYETAL
- - - - PRECIPITATION ISOHYETAL (ESTIMATED)

1 0 1
SCALE IN MILES

FIGURE 4-25

to the variation of individual storms. Precipitation during the winter (January, February, March) was relatively uniform at the three gages, because winter storms are generally regional in nature. Spring precipitation (April, May, June) and summer precipitation (July, August, September) do not illustrate clear trends, which is due to the influence of variations of individual storms.

In comparison to the Baseline period: fall and winter precipitation were about the same; spring precipitation was much less; and summer precipitation was slightly less. Fall and winter were the periods of maximum precipitation, rather than the spring as during the Baseline period. The annual precipitation at the plant site (ARA-13) was about 70 percent of the value for the 1976 water year during the Baseline period. The 16.51 cm (6.50 inches) measured at ARA-13 is also about 65 percent of normal for this area. Precipitation was measured on 41 days during the year at the plant site. The maximum daily amount of precipitation at the plant site during the year was 1.27 cm (0.50 inches) on October 7, 1977, and the maximum amount for an event was 1.78 cm (0.70 inch) on October 6 and 7, 1977. This indicates that no intense storms occurred during the year.

The annual precipitation for the USGS regional network of nineteen gages (shown in Figure 4-20) is listed in Table 4-19. The values range from a maximum of 61.60 cm (24.25 inches) at Weaver Reservoir to a minimum of 14.71 cm (5.79 inches) at Willow Creek near Ouray. The precipitation at these gages had a seasonal distribution that was generally similar to the distribution for the WRSP gages. Annual and seasonal precipitation generally increased from northwest to southeast, as the elevation increased. The comparison of the isohyetal lines for this network to the measured amounts of annual precipitation at the

TABLE 4-19

ANNUAL PRECIPITATION
USGS REGIONAL NETWORK
OCTOBER 1977 - SEPTEMBER 1978

Location Name	Latitude	Longitude	Annual Total (Inches)	Annual Total (cm)	File Number
Sweetwater below South Canyon	392206	1091321	10.69	27.15	18
Sweetwater at mouth	393931	1091958	9.02	22.91	19
Evacuation Creek above Missouri Creek	394752	1094030	9.42	23.93	20
Bitter Creek above Dick Canyon	393203	1090549	15.70	39.88	21
McCook - Indian Ridge	393646	1092560	8.55	21.72	22
South Canyon, snow co.	392732	1091508	16.82	42.72	23
White River near Colo. state line	400050	1090448	7.69	19.53	24
Willow Creek near Ouray	395630	1093900	5.79	14.71	25
Hill Creek above Towave	393130	1094354	8.54	21.69	26
Willow Creek below Big Canyon	393358	1093518	7.27	18.47	27
Hill Creek near mouth	395235	1094329	5.92	15.04	28
Bitter Creek near Bonanza	394512	1092115	9.56	24.28	29
Sandwash near Ouray	395601	1092946	6.30	16.00	30
Bitter Creek at mouth	395758	1092459	6.99	17.75	31
Bitter Creek corral	394933	1092428	6.91	17.55	32
Buck Canyon - Seep Ridge	394422	1092955	6.11	15.52	33
White River at mouth	400354	1093806	6.80	17.27	34
Baxter Pass	393520	1090056	21.39	54.33	35
Weaver Reservoir	391315	1094505	24.25	61.60	36

WRSP gages is shown in Figure 4-26. The estimates based on the isohyetal lines are close for RV-7, but are about 25 percent too high for ARA-13 and RV-8. The differences are mostly due to the effects of variations of individual storms, which are not described by the isohyetal method used for this analysis. This is because the five closest USGS gages are 8 to 16 kilometers (5 to 10 miles) from the WRSP gages, and individual thunderstorms in the vicinity of the tracts often show considerable variation within this range of distance.

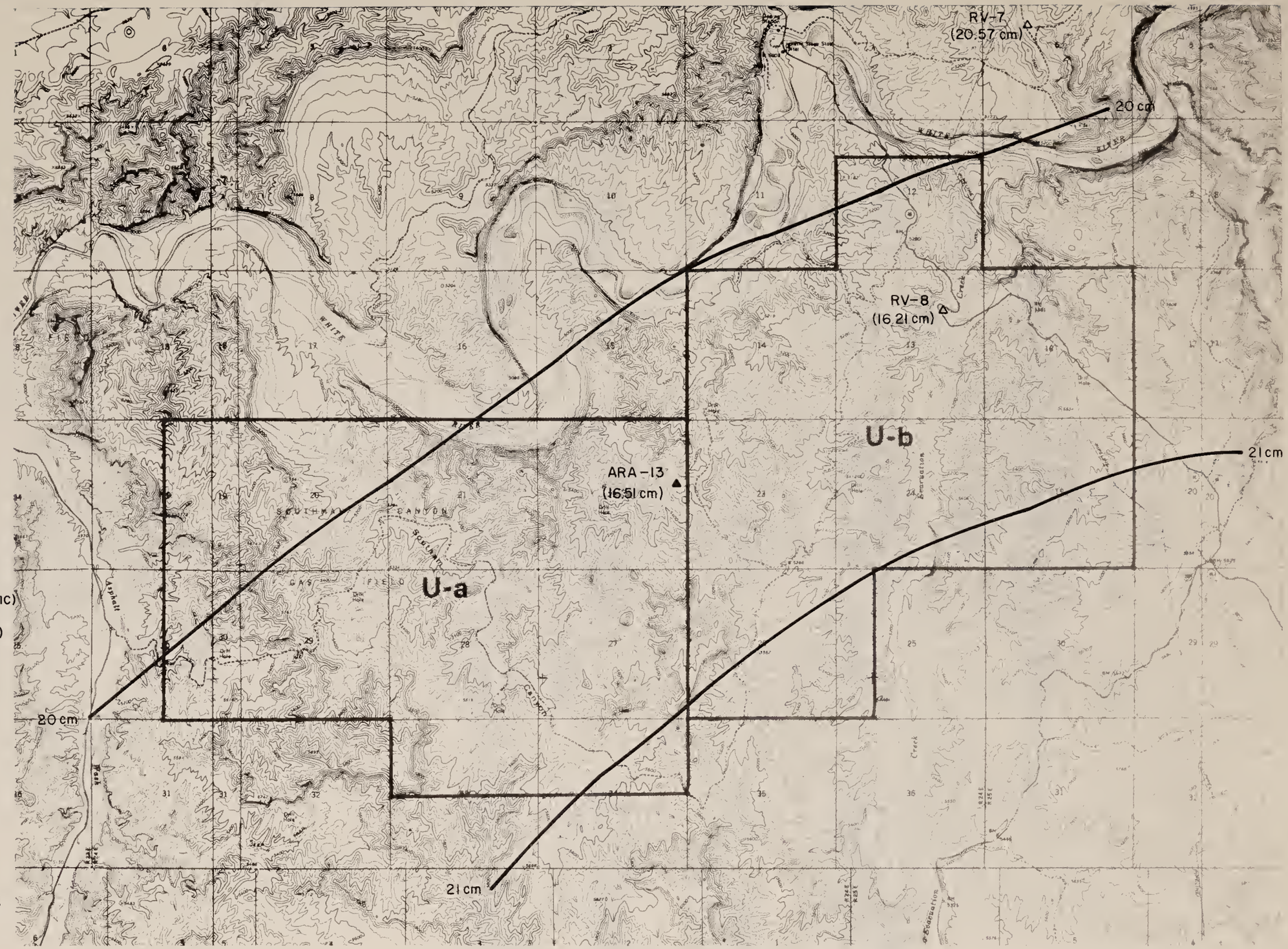
Evaporation

The net pan evaporation at EVP-2 and EVP-13 for the freeze-free period from May through September is shown in Table 4-20. At EVP-2, net pan evaporation was slightly less than it was in 1975 and 1977 (92 cm vs. 84 cm), and slightly greater than it was in 1976. AT EVP-13, net pan evaporation was slightly greater than it was in 1977 (72 cm vs. 62 cm). The greatest amount of net pan evaporation occurred during June and July at both locations.

A comparison of net evaporation, precipitation and total evaporation at EVP-2 and EVP-13 during 1977 and 1978 is shown in Table 4-21. At EVP-2, total evaporation decreased from 1977 to 1978; while at EVP-13, it increased. The difference in total evaporation between the two stations decreased from 1977 to 1978.

4.1.4.4 Conclusions. Precipitation data from the site specific gages indicate that the annual precipitation at the plant site for the 1978 water year was less than during the Baseline period (70 percent of 1976 annual precipitation) and also less than the historic average (65 percent of normal). This was due mostly to well below normal seasonal precipitation in the spring. Although about the same number of precip-

COMPARISON OF WRSP PRECIPITATION GAGES TO USGS REGIONAL PRECIPITATION NETWORK, OCT 1977 – SEP 1978



LEGEND

- ▲ WRSP PRECIPITATION GAGE (AUTOMATIC)
- △ WRSP PRECIPITATION GAGE (STORAGE)
- — USGS REGIONAL PRECIPITATION ISOHYETAL LINE

FIGURE 4-26

TABLE 4-20

PAN EVAPORATION
MAY 1978 - SEPTEMBER 1978

	EVP-2	EVP-13
May	5.375	3.840
June	9.225	7.300
July	9.275	7.450
August	6.950	6.100
September	5.475	3.850
May-Sept.	36.300 in. (92.202 cm.)	28.540 in. (72.492 cm.)

Note: The record for EVP-2 is from May 6 through September 19. The record for EVP-13 is from May 5 through September 19.

TABLE 4-21

COMPARISON OF EVAPORATION AND PRECIPITATION
AT EVP-2 AND EVP-13
DURING 1977 and 1978

Station	Net Evaporation Change from 1977 to 1978 inches	cm	percent	Precipitation Change from 1977 to 1978 inches	cm	percent	Total Evaporation Change from 1977 to 1978 inches	cm	percent
EVP-2	-1.97	-5.00	-5.1	-1.90	-4.83	-52.8	-3.87	-9.83	-9.2
EVP-13	+3.97	+10.08	+16.2	-2.90	-7.37	-78.4	+1.07	+2.71	+3.8

Year	Net Evaporation EVP-2 minus EVP-13 inches	cm	percent	Precipitation EVP-2 minus EVP-13 inches	cm	percent	Total Evaporation EVP-2 minus EVP-13 inches	cm	percent
1977	+13.70	+34.79	+35.8	-0.10	-0.25	-2.8	+13.60	+34.54	+32.5
1978	+7.76	+19.71	+21.4	+0.90	+2.29	+52.9	+8.66	+22.00	+22.8

itation events occurred during 1978 as during the Baseline period, none were intense storms totalling over 2.5 cm (one inch). The data from the Baseline period indicated that, in general, precipitation patterns were affected by terrain (increasing precipitation with increasing elevation), as well as by the variations caused by localized storms. The precipitation patterns during 1978 were variable due to the influence of localized thunderstorms, and did not clearly indicate trends related to terrain. The differences in precipitation between the Baseline period and 1978 are due to expected fluctuations above and below average conditions.

The predicted annual precipitation across the tracts, based on isohyetal lines drawn between USGS regional gages, did not compare closely to the measured annual precipitation at the WRSP site specific gages (a maximum of 25 percent difference). Once again, this was due to the variations caused by individual localized storms.

Measurements of net pan evaporation at EVP-2 were within the range of values during the Baseline period and the 1977 water year. The evaporation pan at EVP-13 was installed in 1977 after the Baseline period. Net evaporation during the 1978 freeze-free period was slightly greater (16 percent) than in 1977. Although the difference between total evaporation at EVP-2 and EVP-13 decreased from 1977 to 1978 (33 percent vs. 23 percent), the difference still seems to be greater than can be accounted by the elevation difference for the two sites. A possible cause for the difference between the two location would be that the wind movement across the pan at EVP-2 is greater than at EVP-13. The EVP-2 location is in Southam Canyon, whereas EVP-13 is located near the top of the ridge separating the Southam Canyon drainage from the Evacuation Creek drainage.

ERRATA
1977 Annual Report
Water Resources

page 4-22: The units for dissolved solids in Figure 7 are mg/l.

page 4-27: The vertical axis for sulfate in Figure 10 should be: 0,100,200,300,400,500.

page 4-60: Under the Evaporation subsection, first paragraph, second sentence should be "Net pan evaporation" rather than "Total pan evaporation".

4.2 AIR RESOURCES

The Interim Air Resources Monitoring Program was designed as a systematic step between the Baseline Monitoring Program and the Development Monitoring Program. The two-year Baseline program was completed by January 1977. At that time the Interim program went into effect. The collection of pertinent air quality and meteorological parameters has continued. During 1977 and 1978 four monitoring stations were operated with one site (A-6) used for air quality monitoring. The data for 1977 was analyzed and summarized in AV Report AV FR-8012. This report analyzes and summarizes the data collected during the Interim monitoring year 1978. The Baseline years referred to in this report are 1975 and 1976. Figure 4-27 shows the locations of the Interim monitoring sites.

4.2.1 Air Quality Monitoring Program

The Interim Air Quality Program was initiated January 16, 1977.

4.2.1.1 Objectives. A prime objective of the program is to determine if the occasional high levels of ozone and non-methane hydrocarbons noted during the Baseline period recur during the lease suspension period. Another objective is to maintain continuity of data on other air quality parameters and to note any significant deviations of values of these parameters from those observed during the Baseline program.

4.2.1.2 Methods. Station A-6 (see Figure 4-27) was operated during the suspension period. The monitoring equipment at Site A-6 has continued in the same fashion as during the Baseline program. Table 4-22 lists the

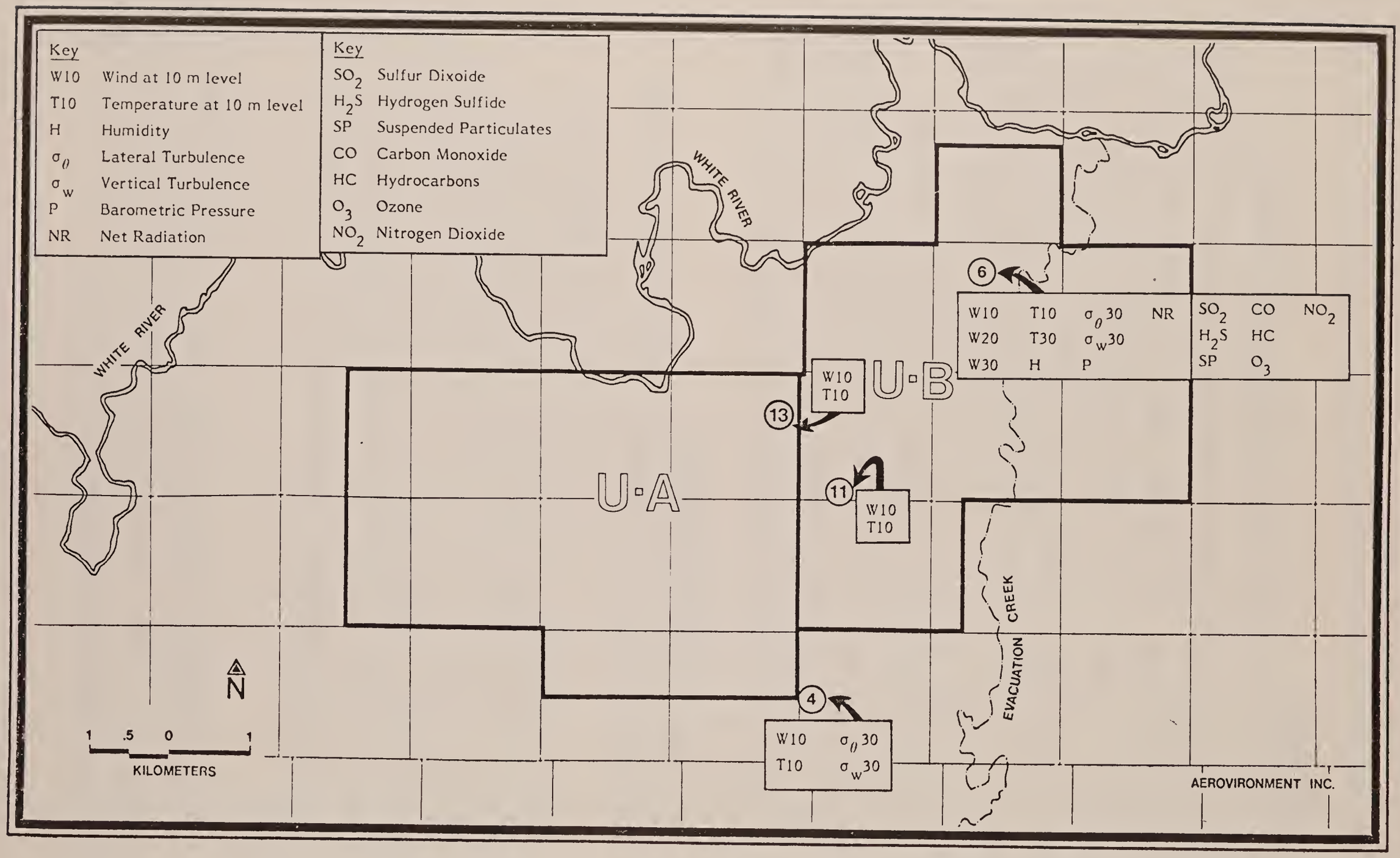


FIGURE 4-27 Locations of meteorological and air quality measurement stations on Tracts Ua and Ub.

TABLE 4-22 Air quality monitoring equipment (Site A6).

Parameters	Instrument
Suspended Particulates	General Metals Model 5000 HiVol w/Constant Flow Control
Sulfur Dioxide, Hydrogen Sulfate, Total Sulfur	Tracor 270 HA Sulfur Analyzer-Gas Chromatography
Nitrogen Oxides (NO, NO_x, NO_2)	Monitor Labs Model 8440 NO_x Analyzer Chemiluminescence
Hydrocarbons (Total hydrocarbons, CH_4)	Beckman 6800 Gas Chromatograph, Flame Ionization
Carbon Monoxide	Beckmann 6800 Gas Chromatograph, Flame Ionization
Oxidants (O_3)	Monitor Labs 8410, Ozone Analyzer, Chemiluminescence

instruments used and the parameters measured. All parameters, except suspended particulates, are monitored continuously. Data are recorded on digital punch tapes every 6 minutes and on strip charts every 2 minutes.

Station A-3 is maintained on a standby basis. A-3 has the same instrumentation as A-6 and would be put into service if A-6 becomes inoperable.

Suspended particulates are measured over a 24 hour period at A-6 every sixth day. This schedule is the same as used in the Baseline Monitoring Program and is considered sufficient for continued characterization of the randomly produced background particulate material levels. The specific measurement techniques used are the same as those used during the Baseline program, which have been described extensively in previous reports on that program.

Quality assurance was provided through four techniques. First, all of the instruments used during this year were audited 4 times. Second, the air quality equipment was recalibrated (dynamic multiple point) monthly, and third, the equipment received span and zero checks every two days. This schedule of calibration is more frequent than that for the Baseline program. It reflected the greater reliability demanded of a single air monitoring station. Fourth, in addition to the normal internal quality assurance procedures maintained by AeroVironment, the White River Shale Project was participating voluntarily in an air pollution measurement quality assurance program implemented by the Environmental Protection Agency. An in-depth description of the quality assurance program in contained in the report "AV-QA-8047, Quality Assurance Plan for Air Resources Monitoring, Oil Shale Lease Tracts Ua-Ub (AV, 1978)."

4.2.1.3 Present Status and Plans for 1979

The extent of the air quality data collected during 1978 is tabulated in Table 4-23. This table lists the percentage of hours during this period that data collection was underway for each parameter. Calibration time is counted as data collection time. The Beckman 6800 Gas Chromatograph, which measures THC, CH_4, and CO, was frequently out-of-service during the second half of 1978. This resulted in the lower than normal percentage data recovery for THC, CH_4, and CO.

4.2.1.4 Data Summary

Gaseous Pollutants

Both gaseous and particulate air quality measurements were made at station A-6. There are no Utah State air quality standards for gaseous pollutants, while Federal standards exist for all components except H_2S. For reference in the ensuing discussions Table 4-24 presents the Federal Ambient Air Quality Standards (AAQS) for the various gaseous pollutants monitored on the tracts. The new standard for ozone of 240 $\mu g/m^3$ (.12 ppm) went into effect on January 26, 1979. For H_2S, a reference for interpreting the data is the California 1-hour standard of 42 $\mu g/m^3$ (.03 ppm).

The air quality continued to be consistently very good on the tracts. During this study period, except for sporadic occurrences of high non-methane hydrocarbon (NMHC), the air on the tracts was very clean with respect to gaseous pollutants. The only other pollutant that was present in measurable quantities was ozone, which has a natural non-zero background level. Otherwise almost all instruments measuring gaseous pollutants were recording at their threshold limit most of the time, the same as during the Baseline period.

TABLE 4-23 Percentage of time monitoring was performed for air quality parameters during 1 January - 31 December 1978.

Component	# of Stations	Percentage
SO_2	1	86
H_2S	1	85
Total HC	1	67
NO_x	1	96
O_3	1	97
CO	1	68
Suspended Particulates	1	84

TABLE 4-24 Federal air quality standards for gaseous pollutants.

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Ozone (O_3)	1 hour	240 $\mu g/m^3$ (0.12 ppm)	Same as primary
Carbon Monoxide	8 hours	10 mg/m^3 (9 ppm)	Same as primary
	1 hour	40 mg/m^3 (35 ppm)	Same as primary
Sulfur Dioxide SO_2	Annual Average	80 $\mu g/m^3$ (0.03 ppm)	-
	24 hour	365 $\mu g/m^3$ (0.14 ppm)	-
	3 hour	-	1300 $\mu g/m^3$ (0.5 ppm)
Nitrogen Dioxide No_2	Annual Average	100 $\mu g/m^3$ (0.05 ppm)	Same as primary
Hydrocarbons (corrected for methane - NMHC)	3 hour (6-9 a.m.)	160 $\mu g/m^3$ (0.24 ppm)	Same as primary

Comparisons are made with the Baseline monitoring data to determine any significant changes in results. Generally, the data do not exhibit any significant abnormalities from the Baseline data. Specific comments are included with the discussion of each parameter when appropriate.

1. Ozone (O_3)

Plots of diurnal variations of O_3 at site A-6 for January, April, July and October 1978 are presented in Figures 4-28 through 4-31. The months of January (winter), April (spring), July (summer) and October (fall) are presented as representative of each season. The average diurnal trend consists of low readings of about 40 $\mu g/m^3$ in the early morning hours and high values in the afternoon hours.

The mean baseline hourly values are also shown. The average value for January and July 1978 was 5 - 10 $\mu g/m^3$ greater than the average Baseline ozone. April was a little less and October was the same as Baseline. The nominal detection limit for the ozone analyzer is 2 $\mu g/m^3$. Since the instrument's precision is $\pm$ 10 $\mu g/m^3$, the difference between the Baseline and Interim periods does not appear to be significant.

The peak hour, second highest hour, average seasonal values and number of exceedances are tabulated in Table 4-25. The highest hourly and second highest hourly values during 1978 were 137 $\mu g/m^3$ and 135 $\mu g/m^3$ respectively. The average values by seasons of the year ranged between 58 and 78 $\mu g/m^3$ which is slightly above the typical global background value.

Highest concentrations ($\geq$120 ug/m^3)occurred on the tracts with a westerly wind. This is the prevailing direction during the afternoon hours during the summer months.

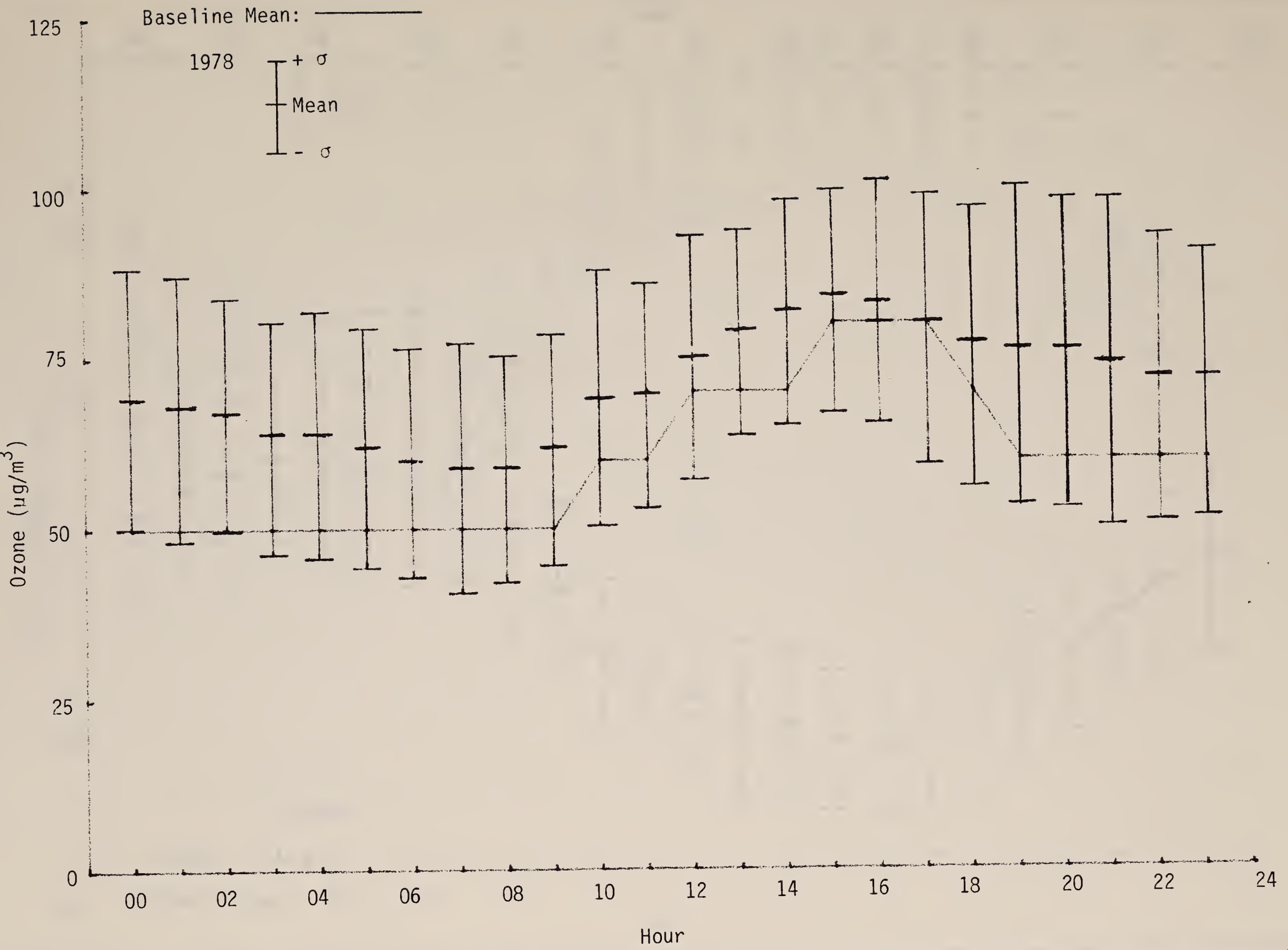


FIGURE 4-28 Diurnal variation of mean ozone concentrations with their standard deviations during 1978 compared with the baseline mean values at Site A6 during January.

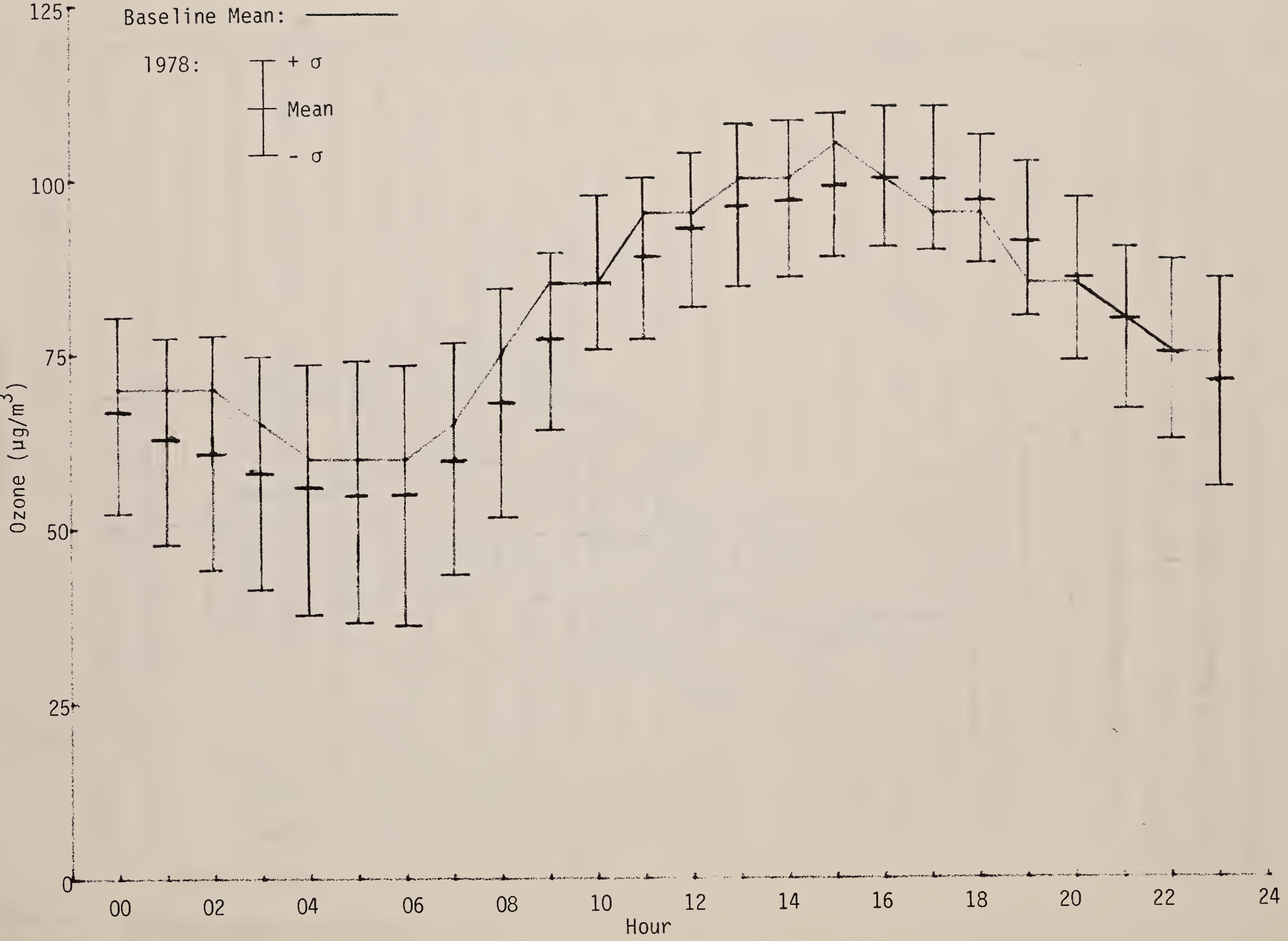


FIGURE 4-29 Diurnal variation of mean ozone concentrations with their standard deviations during 1978 compared with the baseline mean values at Site A6 during April.

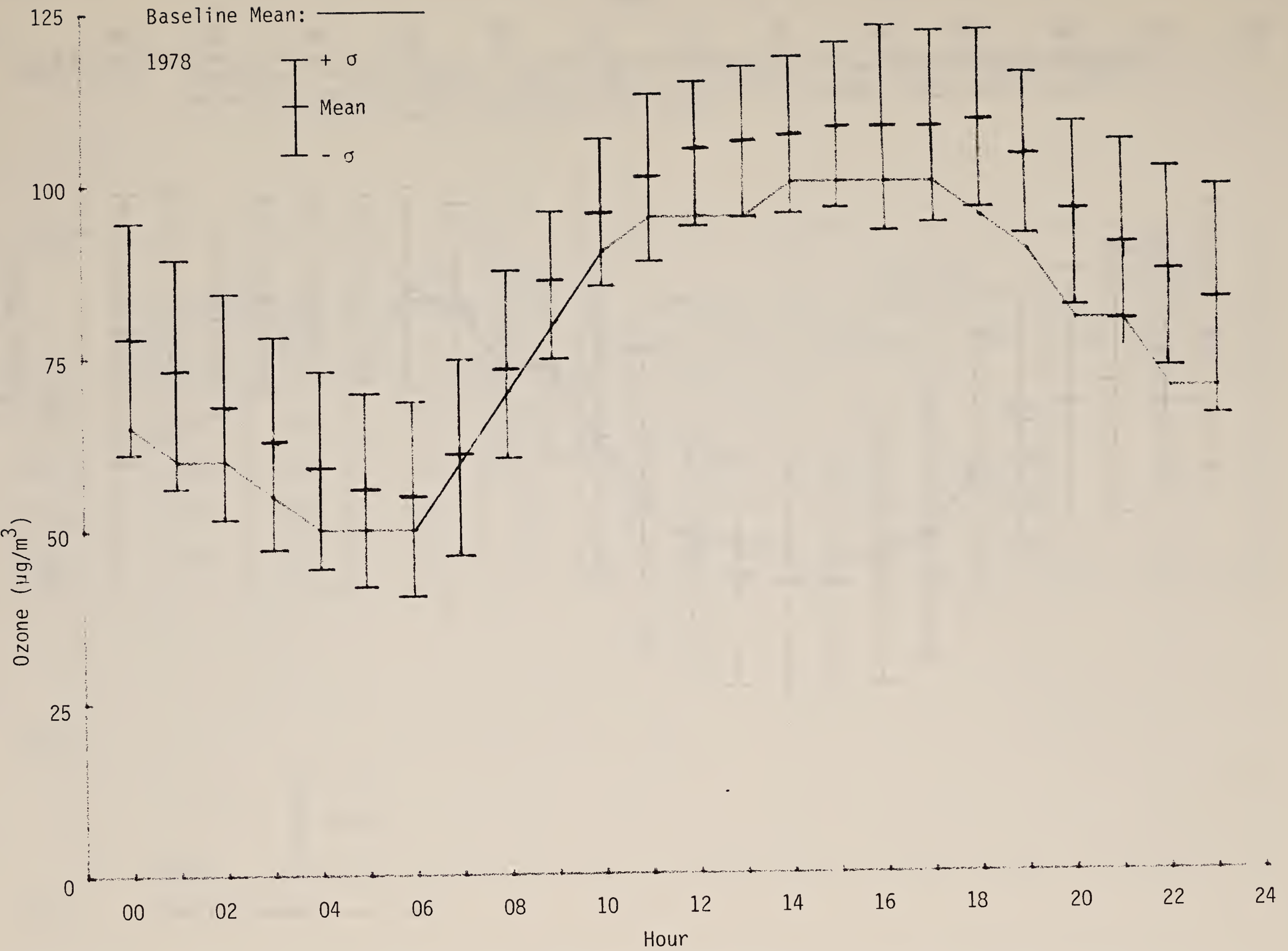


FIGURE 4-30 Diurnal variation of mean ozone concentrations with their standard deviations during 1978 compared with the baseline mean values at Site A-6 during July.

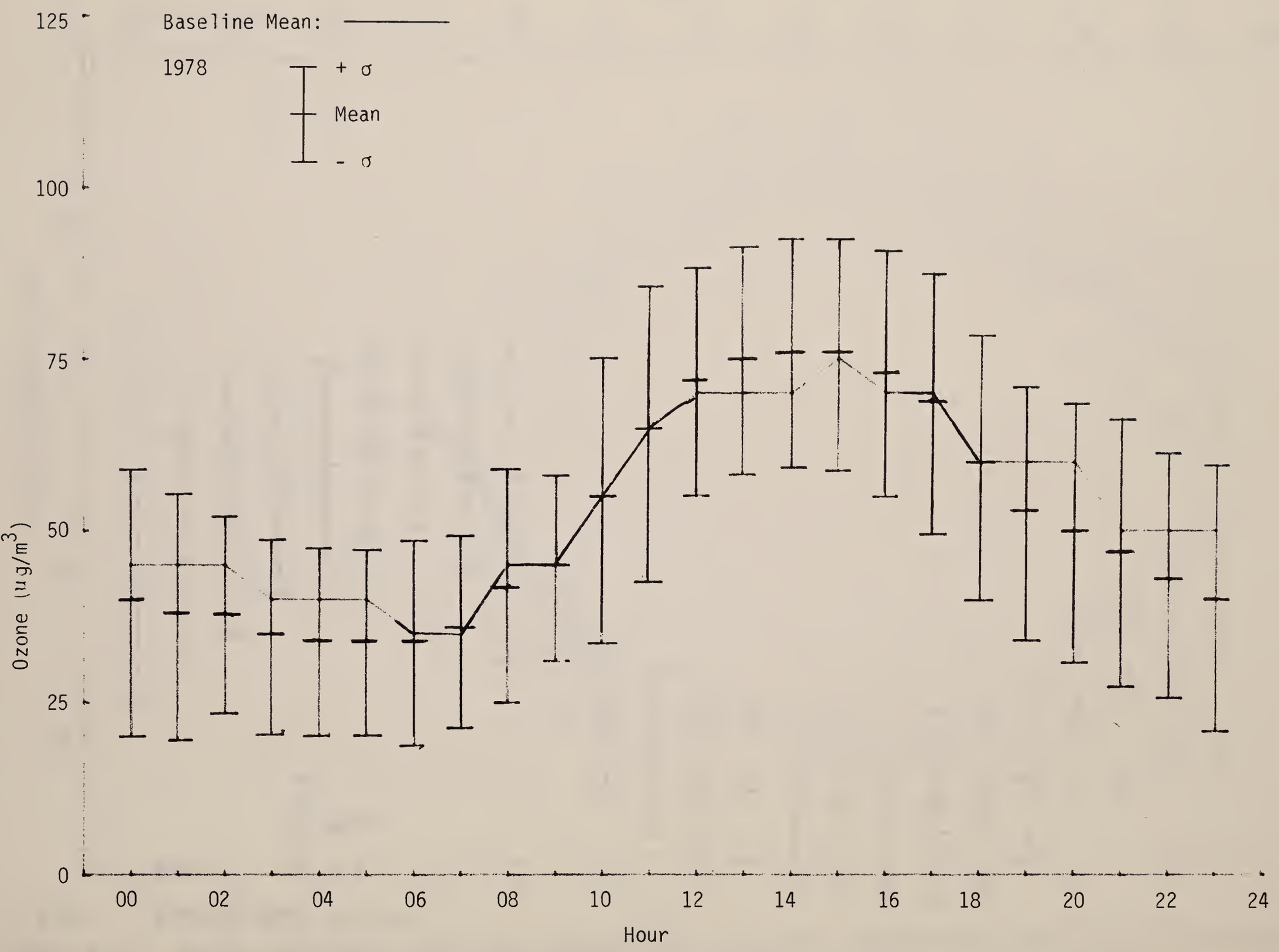


FIGURE 4-31 Diurnal variation of mean ozone concentrations with their standard deviations during 1978 compared with the baseline mean values at Site A6 during October.

TABLE 4-25 Comparison of the highest, second highest and average 1-hour O_3 readings (in $\mu g/m^3$) as well as the percent of observations exceeding the standard (160 $\mu g/m^3$) at Site A6 from the Baseline Period (1975-1976) and 1978.

Season	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978
Winter	150	133	150	131	70	74	2,872	2,081	0	0
Spring	150	137	140	135	75	78	4,033	2,166	0	0
Summer	140	131	140	129	75	77	4,135	2,058	0	0
Fall	140	123	120	122	55	58	4,244	1,743	0	0

Figure 4-32 shows the monthly maximums and means as well as the mean daily maximum hourly averages for 1978 compared to the Baseline period. The highest maximums and means occur from late winter with a minimum through late summer.

This seasonal variation in ozone concentrations is best explained by Figure 4-33, which is an excerpt from a report by Singh, et al (1977). The existence of a large natural ozone reservoir in the troposphere, especially in late winter and early spring, would account for the high readings on Tracts Ua/Ub during that period. Throughout summer, high ozone readings are probably attributed to ozone generations from local or transported precursors, with occasional long-range transport from urban areas.

2. Carbon Monoxide, CO

Table 4-26 presents the highest, second highest and average 1-hour and 8-hour CO concentration at Site A-6. The maximum 1-hour and 8-hour readings during 1978 were 0.7 and 0.4 mg/m^3, which were lower than the 3.0 and 1.8 mg/m^3 recorded during the Baseline period. However, all values were well below the national standards of 40 mg/m^3 (1-hour) and 10 mg/m^3 (8-hour).

Contamination of CO readings by generator exhaust was a problem during the first part of the Baseline period. The normal background level is 0.5 mg/m^3 and practically all of the readings fall around and below this value.

No diurnal or seasonal variations were observed in the CO levels. Readings were generally near the detection limit of the instrument, 0.1 mg/m^3 (0.1 ppm).

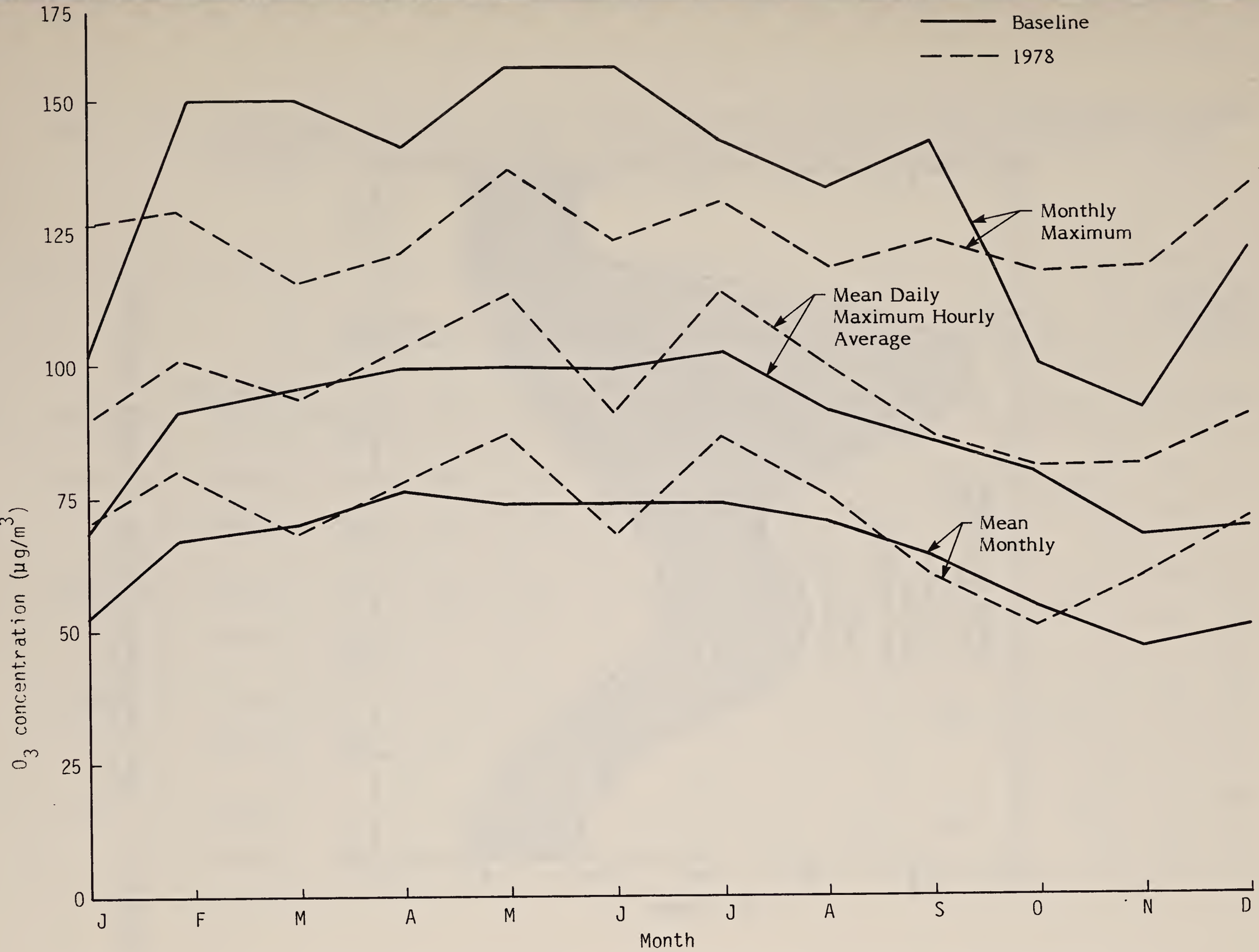


FIGURE 4-32 Monthly maximum hourly value, mean daily maximum hourly average, and mean monthly value for O_3 at Site A6 for 1978 compared to the previous three years.

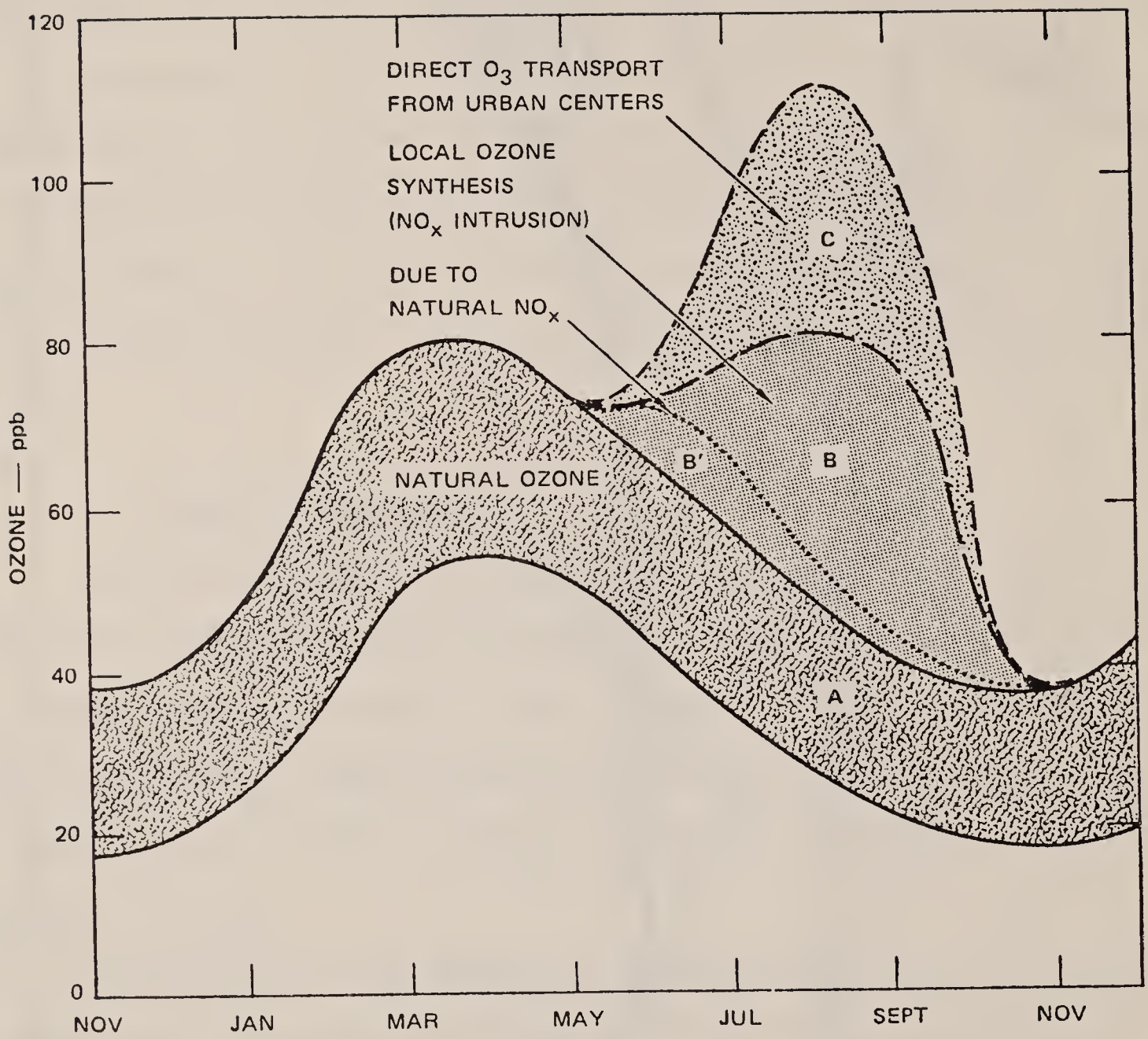


FIGURE 4-33 Idealized ozone variations at remote locations (From Singh, et al, 1978).

TABLE 4-26 Comparisons of the peak, second highest, and average 1-hour and 8-hour moving mean CO readings (in mg/m^3), as well as the number of observations exceeding the standard (40 mg/m^3, 1-hour; 10 mg/m^3, 8-hour) at Site A6 for the baseline period (1975, 1976) and 1978.

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Average		Number of Observations		Number of Exceedances of Standard	
		Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978
Winter	1-hour	3.0	0.6	2.2	0.6	0.3	0.1	3,336	1,286	0	0
	8-hour	0.6	0.3	0.5	0.3	0.2	0.1			0	0
Spring	1-hour	0.8	0.7	0.7	0.5	0.1	0.0	3,327	2,147	0	0
	8-hour	0.3	0.3	0.3	0.3	0.1	0.0			0	0
Summer	1-hour	3.0	0.5	2.7	0.4	0.2	0.1	2,038	1,707	0	0
	8-hour	1.8	0.4	1.7	0.4	0.1	0.1			0	0
Fall	1-hour	1.2	0.5	1.2	0.3	0.2	0.0	3,545	281	0	0
	8-hour	0.3	0.2	0.3	0.1	0.1	0.0			0	0

3. Nitrogen Dioxide, NO_2

Of the nitrogen oxides, only NO_2 has a Federal ambient air quality standard (annual average of 100 $\mu g/m^3$). Table 4-27 shows the annual averages for both the Baseline and Interim periods. The California standard (for reference) is a 1-hour average of 470 $\mu g/m^3$. This table also shows the highest, second highest and average of 1-hour averages. Again, activity on the tracts during the first part of the Baseline Program could have produced the high values of 100 $\mu g/m^3$.

The precision of the instrument is around 20 $\mu g/m^3$ and readings are generally below this value and near the lower detection limit of this instrument (5 $\mu g/m^3$). No seasonal trends are evident.

4. Sulfur Dioxide, SO_2

Table 4-28 gives the 1978 and Baseline comparison of the highest, second highest, average and percent exceedance of both the 3-hour and 24-hour readings of SO_2.

No seasonal or diurnal trend has been evident and most values are near the detection limit of 10 $\mu g/m^3$ (8 ppb). The highest 3-hour SO_2 reading of 27 $\mu g/m^3$ was recorded during fall of 1978. The standard for a 3-hour averaging time is 1,300 $\mu g/m^3$. The highest 24-hour SO_2 reading was 14 $\mu g/m^3$ and was recorded in the spring 1978. Again, this reading is well below the 24-hour standard of 365 $\mu g/m^3$. The annual average on the tracts is 3 to 4 $\mu g/m^3$ as compared to the annual standard of 80 $\mu g/m^3$. Most values have been near the detection limit of the instrument (20 $\mu g/m^3$).

TABLE 4-27 The peak, second highest and average hourly-averaged NO_2 concentrations ($\mu g/m^3$) as well as the number of observations exceeding the 1-hour standard (470 $\mu g/m^3$) at Site A6 for the Baseline Period and 1978.

Season	Peak Concentration		Second Highest Concentration		Average		No. of Observations		Number of Exceedances of Standard	
	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978
Winter	20	15	20	13	5	3	2,460	2,090	0	0
Spring	20	8	20	2	5	0	3,984	2,122	0	0
Summer	100	9	90	6	15	0	3,600	1,782	0	0
Fall	100	9	80	9	10	2	3,996	2,145	0	0
Annual	-	-	-	-	9	1	2	1	0	0

TABLE 4-28 The peak, second highest, and average hourly averaged SO_2 concentrations ($\mu g/m^3$), as well as the number of observations exceeding exceeding the 3-hour standard (1300 g/m^3, 24-hour standard (365 $\mu g/m^3$) at Site A6 during the baseline period (1975, 1976) and interim period (1978).

Season	Averaging Time	Peak Concentration		Second Highest Concentration		Average		Number of Observations		Number of Exceedances of Standard	
		Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978
Winter	3-hour	10	10	5	9	3	2	1,144	690	0	0
	24-hour	5	3	5	3	3	1	143	87	0	0
Spring	3-hour	10	18	10	18	3	3	1,216	722	0	0
	24-hour	5	10	5	8	3	2	152	92	0	0
Summer	3-hour	10	11	10	10	4	3	1,136	370	0	0
	24-hour	5	9	5	9	3	3	142	47	0	0
Fall	3-hour	5	27	5	19	3	7	1,376	728	0	0
	24-hour	5	14	5	13	3	6	172	91	0	0
	Annual	-	-	-	-	2	3	2	1	0	0

5. Hydrogen Sulfide, H_2S

Since there are no Federal standards for H_2S, a reference for interpreting the data is the California 1-hour standard of 42 $\mu g/m^3$.

Most readings are below the detection limit 10 $\mu g/m^3$ (.008 ppb) of the instrument. Table 4-29 gives the comparisons of the Baseline and Interim periods with highest, second highest, average and percent of exceedance of the California Standard. Some values during the initial time of the Baseline period were higher and probably locally-induced by tract activity.

No diurnal or seasonal trends were evident. The highest value of 30 $\mu g/m^3$ was recorded during the beginning of the Baseline period when tract activity was high. The highest hourly value during 1978 was 10 $\mu g/m^3$ in the spring.

6. Non-Methane Hydrocarbon (NMHC)

The precision of the Beckman gas chromatograph for the analysis of hydrocarbons is 0.1 ppm (70 $\mu g/m^3$) for THC (total hydrocarbons) and 0.1 ppm for CH_4 (methane). To obtain NMHC, the CH_4 reading is subtracted from the THC reading. This compounds an error to about 0.2 ppm (130 $\mu g/m^3$), and considerably larger errors are possible on a sample-to-sample basis. Since the NMHC standard 160 $\mu g/m^3$, the instrumentation precision is inconsistent with the standard, even if perfectly calibrated. However, the EPA prescribed reference method for measuring non-methane hydrocarbons is by flame ionization detection and gas chromatography, exactly as used in the Beckman instrument, and the measurement procedures used during the program are the best available. This inconsistency between the ambient air quality standard and the instrumentation technique is recognized by

TABLE 4-29 The peak, second highest, and average hourly-averaged H_2S concentrations ($\mu g/m^3$), as well as the number of observations exceeding 42 $\mu g/m^3$ at Site A6 for the baseline period (1975, 1976) and the interim period (1978).

Season	Peak Concentration		Second Highest Concentration		Average		Number of Observations		Number of Exceedance 42$\mu g/m^3$	
	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978	Baseline	1978
Winter	20	3	20	2	5	0	1,320	1,984	0	0
Spring	30	10	30	3	10	1	1,680	2,140	0	0
Summer	20	5	15	4	5	1	1,440	1,066	0	0
Fall	5	4	0	4	0	1	2,040	2,142	0	0

the EPA. In early 1978, EPA issued a letter discouraging the monitoring of NMHC on oil shale lease tracts. Following EPA's suggestion and with the approval of the Area Oil Shale Supervisor, total hydrocarbons (THC) and methane (CH_4) were monitored in 1978 but NMHC values were not developed.

Suspended Particulate, TSP

Particulate concentrations are monitored by means of high volume samplers which sample over a period of 24 hours once every six days. The size of the particulate matter collected by the samplers ranges from below 1 μm to 100 μm.

Table 4-30 gives the geometric mean, standard geometric deviation, maximum and minimum of the total suspended particulate concentrations in $\mu g/m^3$ at Site A-6. The Baseline period and 1978 are shown by season.

The geometric mean presented can be considered to correspond to the maximum concentration to be expected at a 50% frequency because particulate concentrations have been found to be generally log-normally distributed. The geometric mean of particulate concentrations during 1978 ranged from 7.2 $\mu g/m^3$ during the winter months to 27.2 $\mu g/m^3$ during the summer.

None of the recorded values exceeded Federal or State standards, which are presented in Table 4-31. The most stringent short-term standard is the National Secondary Standard, which sets the upper limit at 150 $\mu g/m^3$, averaged over 24 hours; this is not to be exceeded more than once a year. A correlation between 24-hour values of wind speeds and TSP at Site A-6 gave a value of .48, which means poor correlation.

TABLE 4-30 Geometric means, standard geometric deviations, and maximum and minimum of particulate concentrations ($\mu g/m^3$) for baseline period (1975, 1976), and interim period (1978) at Site A6.

	Season	Baseline	Interim
Geometric mean	Winter	14.2*	7.2
	Spring	17.2	14.2
	Summer	37.0	27.23
	Fall	27.2	21.3
Standard Geometric Deviation	Winter	2.6*	1.6
	Spring	1.9	2.2
	Summer	1.4	1.6
	Fall	2.0	2.1
Maximum	Winter	51.9*	13.0
	Spring	42.0	47.7
	Summer	74.7	45.2
	Fall	101.2	62.7
Minimum	Winter	3.5*	2.4
	Spring	4.9	3.3
	Summer	18.7	14.0
	Fall	4.9	4.4
Geometric mean	Annual	24.0	15.0
Standard Geometric Deviation	Annual	2.2	2.2

* 1976 only, insufficient data for 1975.

TABLE 4-31 Ambient air quality standards for particulate matter ($\mu g/m^3$).

Pollutant	Averaging Time	Utah Standards	National Standards	
			Primary	Secondary
Suspended Particulate Matter	Annual Geometric Mean	90	75	60
	24 hour	200	260	150

Background Averages: Table 4-32 gives the annual averages for the pollutants monitored on the tracts from 1975, 1976 (Baseline) through 1977, 1978 (Interim). Generally, the values are slightly less during the last two years. The values recorded during the Interim period are more representative of true background conditions since this was the time that activities on the tracts were at a minimum.

4.2.2 Meteorological Monitoring Program

Meteorological data collection in the Interim Monitoring Program was implemented January 16, 1977. Monitoring equipment at the 4 sites during 1978 are identical to those used during the 2-year Baseline period.

4.2.2.1 Objectives. The objectives of continuing meteorological measurements in the Interim Monitoring Program are to extend the meteorological data base, determine trends, and to provide data verification of Baseline data for use in future air pollutant dispersion modeling work.

4.2.2.2 Methods. The meteorological parameters monitored are shown in Table 4-33. Meteorological data are collected continuously and recorded on digital punch tapes every 6 minutes. Strip charts are also used at Sites A-4 and A-6 for a backup record.

Table 4-34 lists the meteorological monitoring equipment used.

4.2.2.3 Present Status and Plans for 1979

The extent of the data collected during 1978 is tabulated in Table 4-35. This table lists the percentage of hours during this period that data collection was underway for each meteorological parameter.

TABLE 4-32 The annual averages ($\mu g/m^3$) for the gaseous pollutants and annual geometric mean for TSP during the entire period of Baseline (1975, 1976) and Interim (1977, 1978).

Pollutant	Annual Averages			
	Baseline		Interim	
	1975	1976	1977	1978
O_3	75	63	61	58
CO (mg/m^3)	.3	.2	.2	.1
NO_2	6	5	0	1
SO_2	3	0	0	3
H_2S	10	3	0	1
TSP	24.5	23.5	22.2	15.0

TABLE 4-33 Meteorological parameters monitored during lease suspension period.

Parameter	Station			
	A4	A6	A11	A13
Meteorology				
WS/WD - 10 m	X	X	X	X
WS/WD - 20 m		X		
WS/WD - 30 m		X		
T - 10 m	X	X	X	X
ΔT - 10-30 m		X		
σ_θ - 10 m	X			
σ_θ - 30 m		X		
σ_w - 10 m	X			
σ_w - 30 m		X		
Net solar radiation		X		
Dew point		X		
Relative humidity		X		
Barometric pressure		X		

TABLE 4-34 Meteorological monitoring equipment.

Parameters	Instrument	Location
Wind speed and direction	Meteorology Research Inc. Model 1022 anemometer	A6, (10, 20 and 30m) A4 (10m)
Wind speed, direction, and temperature	Meteorology Research Inc. 1071 mechanical weather station	A11 (10m) A13 (10m)
Wind variance	Meteorology Research Inc., R. M. Young anemometer, and AeroVironment Inc. sigma meter	A6 (10 and 30m) A4 (10m)
Temperature and lapse rate	Meteorology Research Inc. thermistors with R. M. Young shield	A6 (10 and 30m) A4 (10m)
Dew point	WeatherMeasure Inc. Model H321S hygrograph	A6

TABLE 4-35 Percentage of time monitoring was performed for meteorological parameters during 1 January - 31 December 1978.

Component	# of Stations	Percentage
Wind (10m)	4	100
Wind (20m)	1	100
Wind (30m)	1	100
Temp. (10m)	4	100
Temp. (30-10m)	1	99
Rel. Hum. (10m)	1	97

Quality assurance for meteorological instruments, in accordance with the Quality Assurance Plan (AV, 1978) was carried out during this period. For some meteorological instruments, off-site calibration is done annually and calibration checks are performed quarterly.

4.2.2.4 Data Summary. The winter of 1977-78 was warm and wet in the western part of the United States. From January to May an almost continuous situation of frontal passages with associated precipitation prevailed in Utah. Temperatures for the winter were way above normal. During the spring only May had below normal temperatures, but above normal rainfall continued to almost June.

Summer was generally normal with warm and dry weather prevailing.

The fall season saw a continuation of relative warmth, with light precipitation. Beginning the middle of November, temperatures dipped below normal and continued on through December. Precipitation, mostly in the form of snow was above normal.

The Interim Program meteorological data for 1978 is presented below and compared quantitatively with the Baseline (1975-1976) program data to determine any significant changes.

Surface Flow

As usual, the rugged terrain features in the area complicated the airflow pattern. Table 4-36 shows the prevailing direction and speed by month for the 4 wind sites. Spatial variation in wind speed on the tracts was observed through the Baseline period. Generally, nighttime drainage flow is prevalent throught the year. Figure 4-34 shows the typical airflow streamlines for the early morning drainage pattern. The solid

TABLE 4-36 Prevailing directions and speeds (m/s) on the tracts during 1978.

Month	Site			
	A4	A6	A11	A13
Jan	W/1.6	WSW/1.3	WNW/1.6	W/1.3
Feb	W/2.0	WSW/1.6	NW/2.0	W/1.1
Mar	W/2.5	ESE/2.5	NW/2.7	W/2.0
Apr	W/3.8	SE/3.8	WNW/4.0	W/3.1
May	W/3.8	SE/3.8	SE/3.8	W/2.9
Jun	SW/4.0	ESE/4.2	SE/3.8	S/3.1
Jul	WNW/3.6	ESE/3.6	NW/3.8	SE/2.9
Aug	WNW/3.6	ESE/3.6	SE/3.6	ESE/2.7
Sep	WNW/3.1	ESE/3.1	SE/3.4	W/2.5
Oct	WNW/2.5	ESE/2.5	SE/2.5	SE/1.6
Nov	WNW/2.0	WSW/1.8	NW/1.8	W/1.6
Dec	W/2.2	ESE/1.6	SE/2.0	W/2.0
Annual	W/2.9	ESE/2.8	SE/2.9	W/2.2

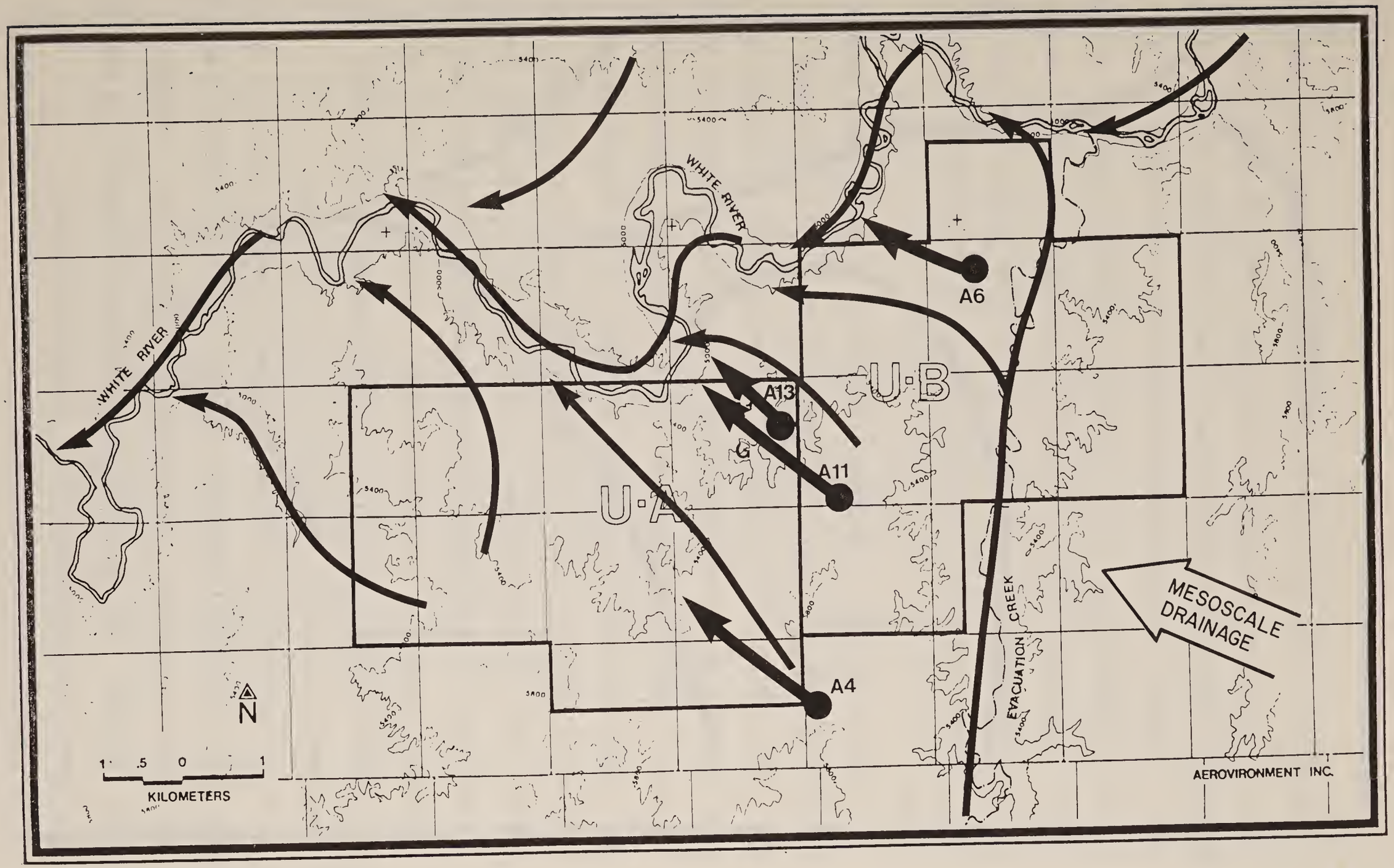
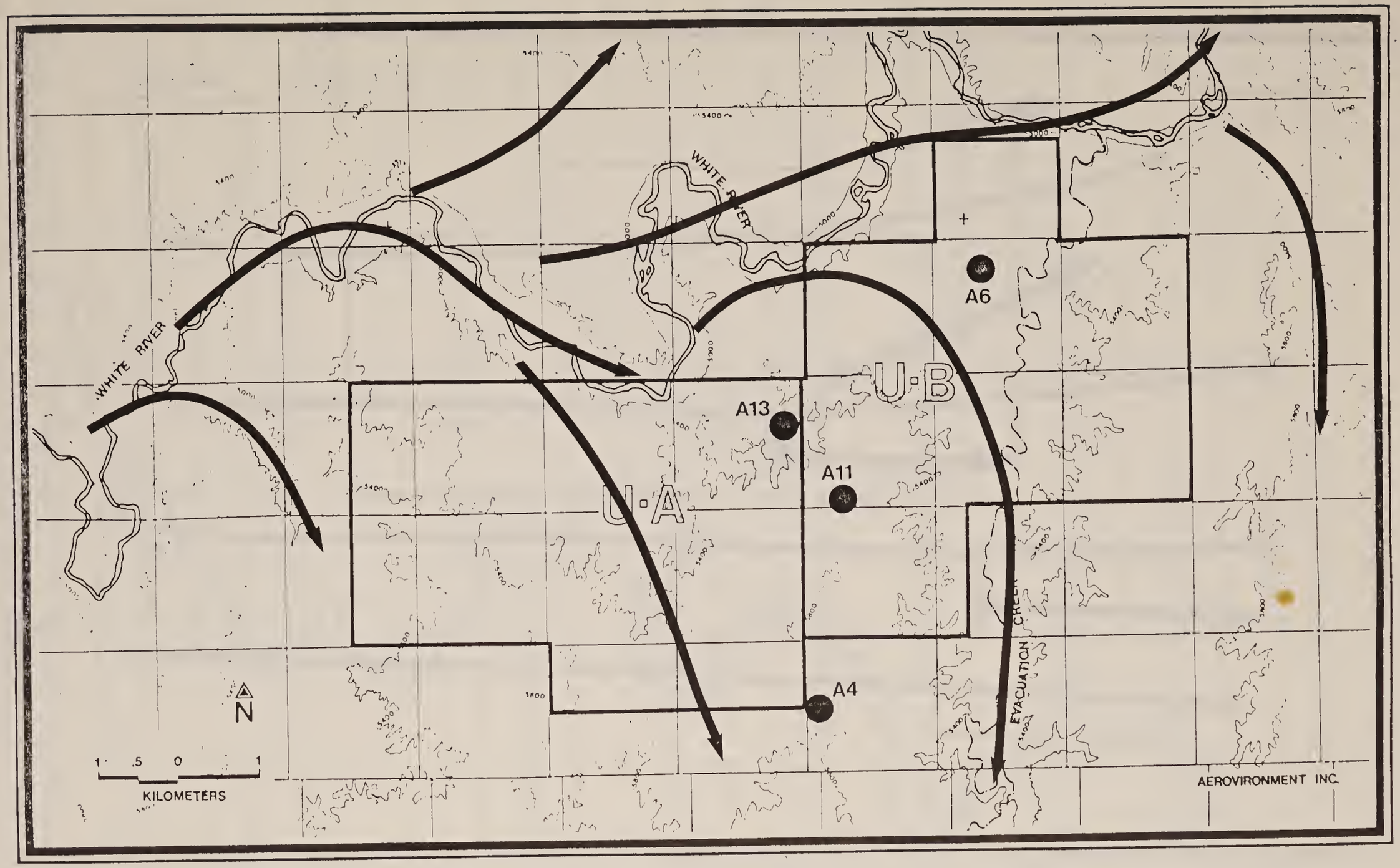


FIGURE 4-34 Typical drainage flow pattern on tracts Ua and Ub during the early morning hours - 1978.

arrows on this figure are wind vectors at the monitoring sites, and the longer lines are estimated flow streamlines. The large open arrow depicts the mesoscale flow direction in the greater White River drainage basin. There is no significant deviation in direction throughout the year in the drainage pattern. This figure was prepared for averaged wind observations at the 4 wind sites for 1978 plus knowledge of the wind flow pattern as presented in reports prepared for the Baseline period. The drainage flow is always from higher to lower terrain, as noted during the Baseline period.

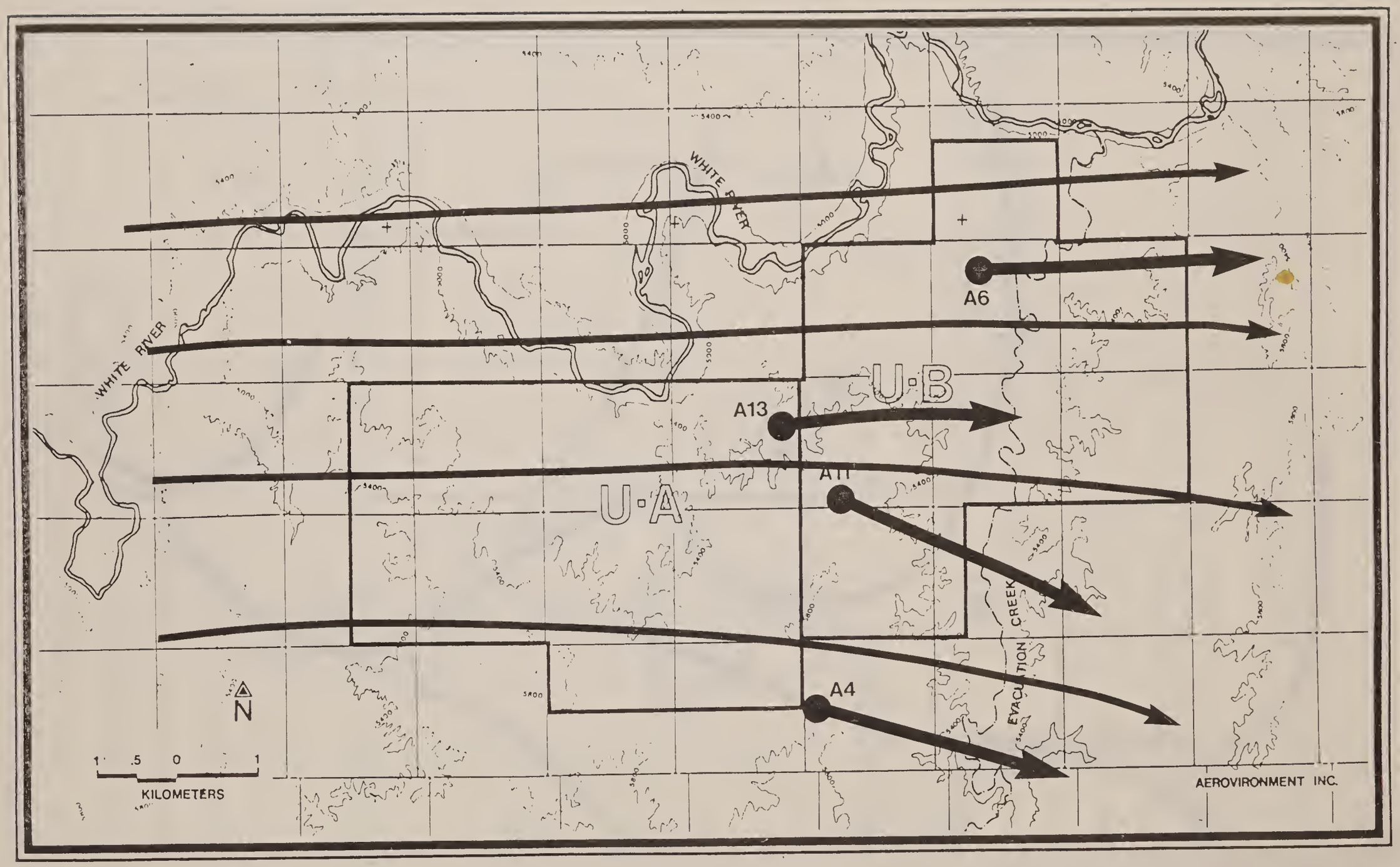
Figure 4-35 shows an upslope pattern that is transitional between drainage and synoptic flow. The surface-based inversion that results from strong radiative cooling begins to lose some of its strength shortly after sunrise. As the morning progresses, the heat gained by the surface from solar radiation exceeds that lost by terrestrail radiation and the soil temperature rises, warming the air above. This creates pressure difference resulting in upslope flow. This pattern is transitional and generally lasts less than an hour, but is important in the understanding of dispersion of pollutants since plume fumigation would occur under this condition. Because of its short duration, this pattern is lost in the hourly-average wind direction. This pattern begins earlier during the summer months than in the winter when the sun rises later.

Figure 4-36 presents afternoon streamlines on the tracts during 1978. Very little directional difference is noted except the average speeds are higher during the summer. No significant difference from the Baseline period is noted. This is the average synoptically-induced flow that is encountered in this portion of Utah throughout the year.



Streamline

FIGURE 4-35 Typical airflow pattern on tracts Ua and Ub during the transitional period - 1978.



2 m/sec
Wind Vector
Streamline

FIGURE 4-36 Typical synoptic airflow pattern on tracts Ua and Ub during the afternoon - 1978.

Figures 4-37 and 4-38 give the average hourly wind speeds for January and July. The July 1978 and Baseline speeds are practically the same during the afternoon. January 1978 wind speeds were much lower than the Baseline averages. The month of January 1978 was unique over the tracts because almost the entire month was under weak prefrontal conditions. By the time the strong, moist Pacific frontal systems moved into Utah they were not supported by strong upper level winds. Consequently, the frontal systems would stagnate by the time they reached Utah. Only on January 23 was there a strong post-frontal condition where the wind speed went over 7 m/s.

Figures 4-39 through 4-42 show the directional wind roses at the monitoring stations on the tracts using the mid-month of the four seasons (January, April, July and October 1978). Although individual months may have different prevailing directions, ESE has been the most prevailing direction at Site A-6 throughout the Baseline and 1977 periods. The frequent occurrence of the ESE wind is a direct result of the drainage flow that exists at A-6. For the year 1978, the greater incidence of storminess increased the percentage of the component from the westerly quadrant.

Temperature

Figure 4-43 presents the diurnal variation in temperature and standard deviation for January and July 1978 at Site A-6. Superimposed on this are the average Baseline values for a comparison. The daily maximum temperature was generally observed between 1400 and 1600 MST, while the daily minimum was observed between 0400 and 0700 MST. The average temperatures were -6^{o}C for January 1978 and 25^{o}C for July 1978. These are shown on Figure 4-44 along with the maximum, mean and minimum

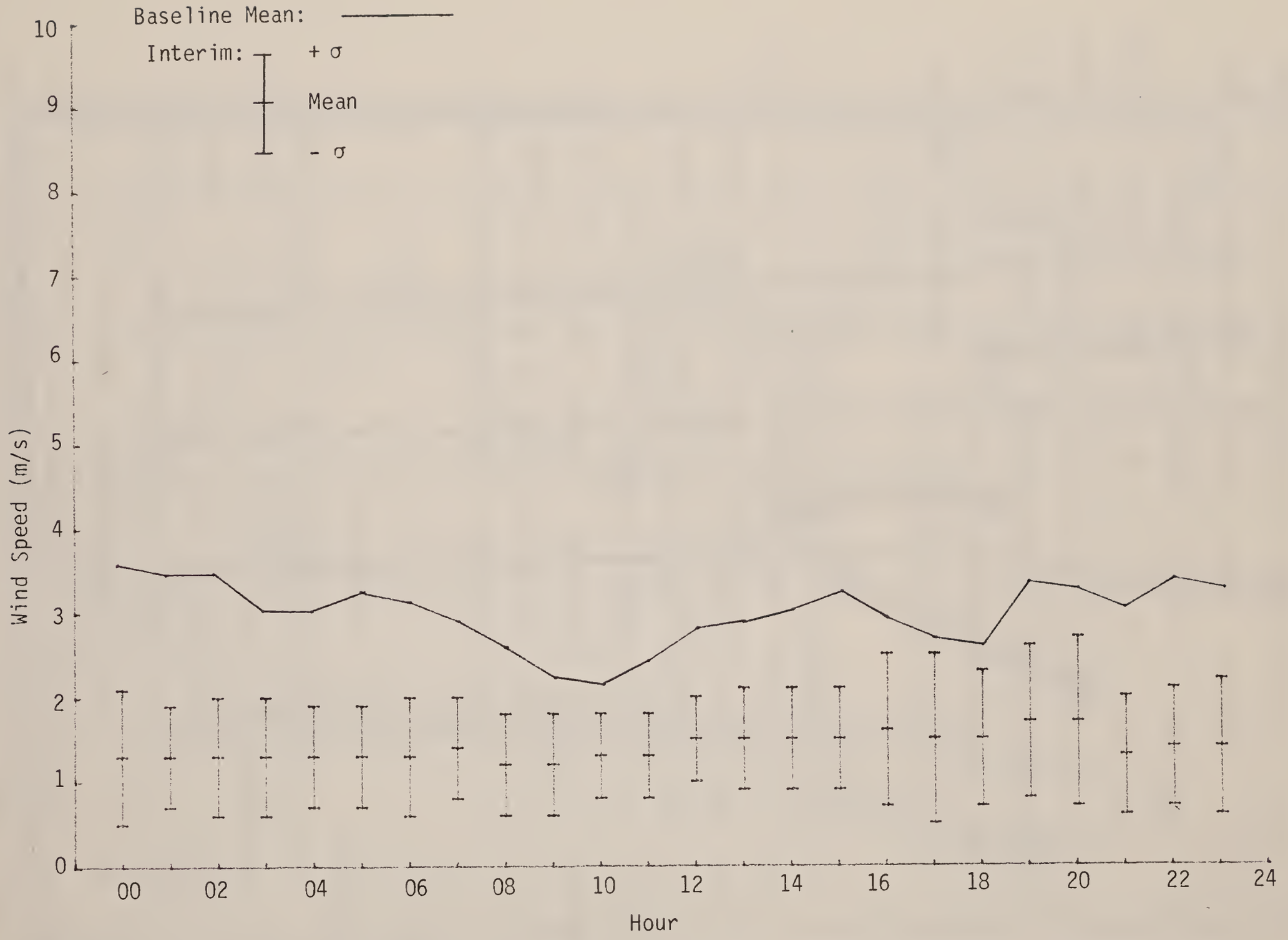


FIGURE 4-37 Diurnal variation of mean wind speeds and their standard deviations, compared to the baseline means at Site A6 during January 1978.

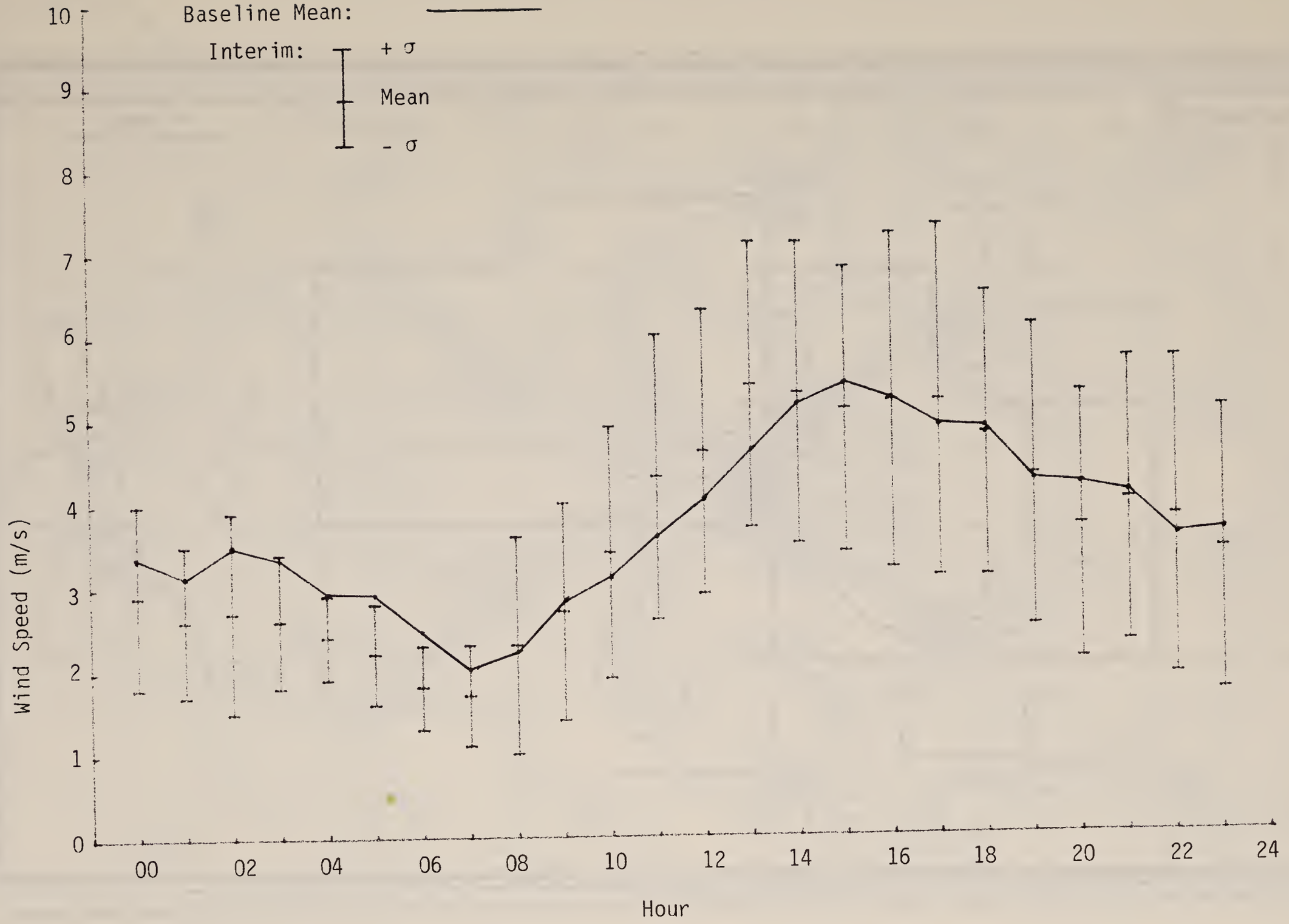


FIGURE 4-38 Diurnal variation of mean wind speeds and their standard deviations, compared to the baseline means at Site A6 during July 1978.

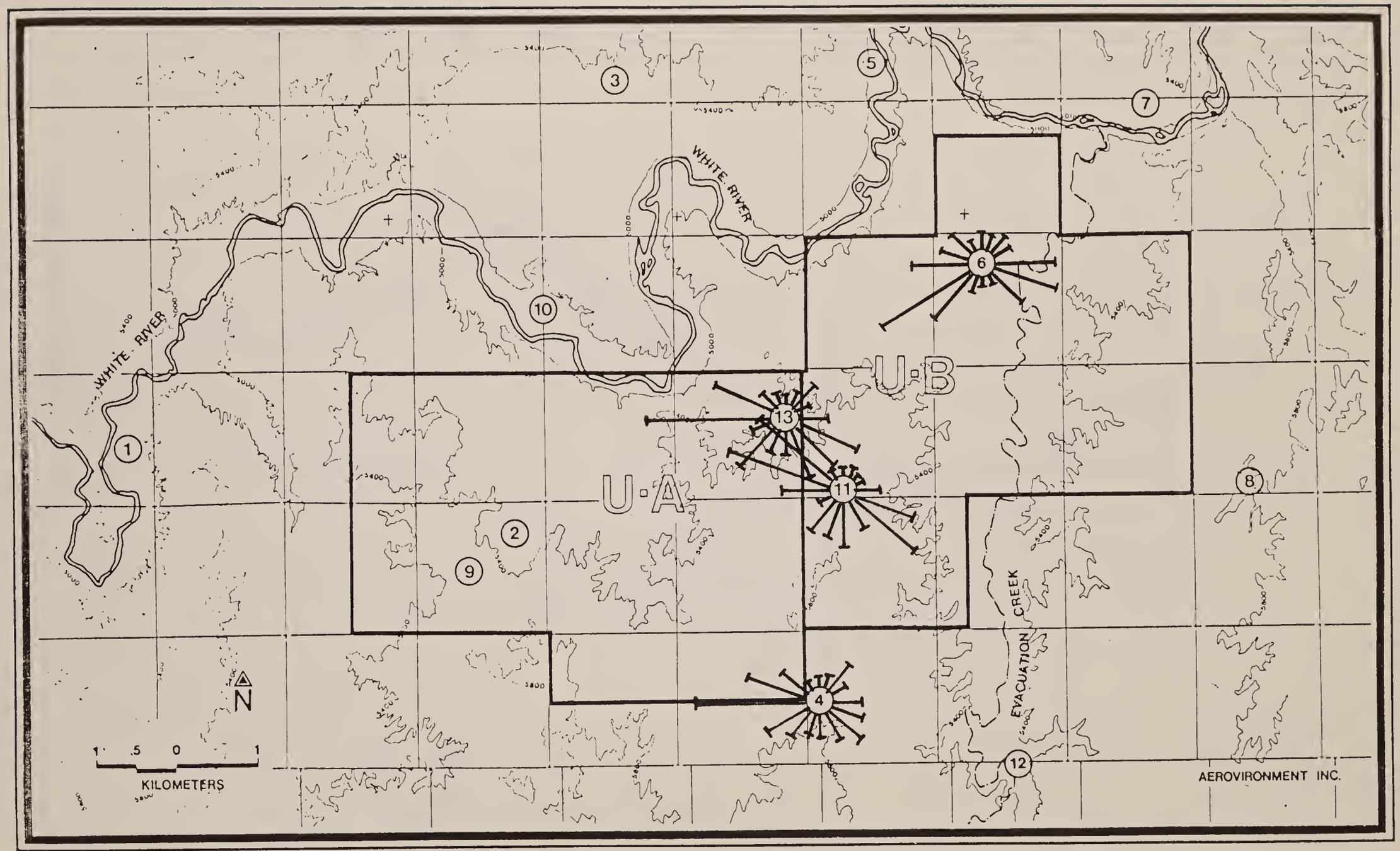


FIGURE 4-39 Directional wind roses at the monitoring stations on the tracts for January 1978. The length of each bar represents the frequency of winds from the direction towards which the bar points.

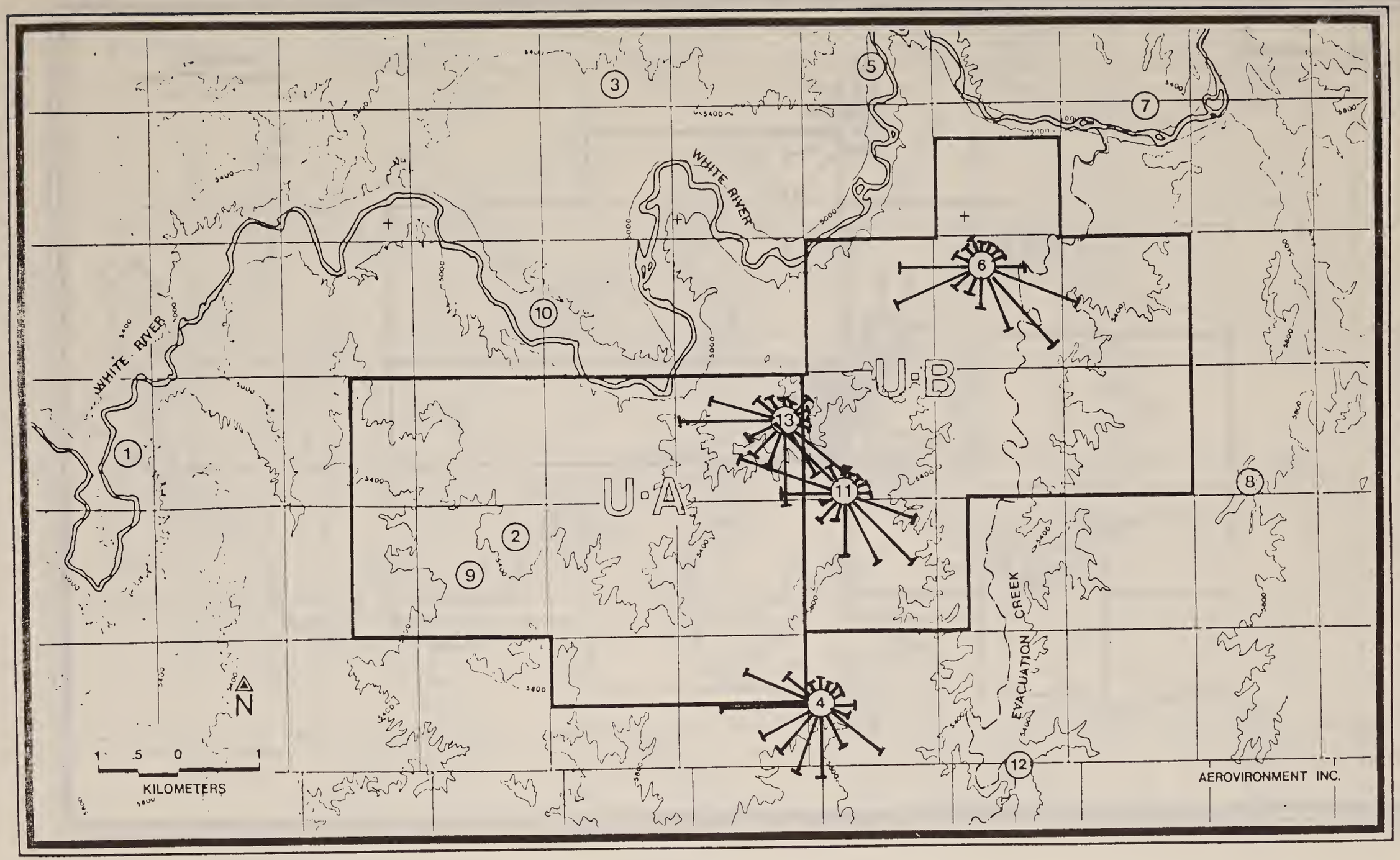


FIGURE 4-40 Directional wind roses at the monitoring stations on the tracts for April 1978. The length of each bar represents the frequency of winds from the direction towards which the bar points.

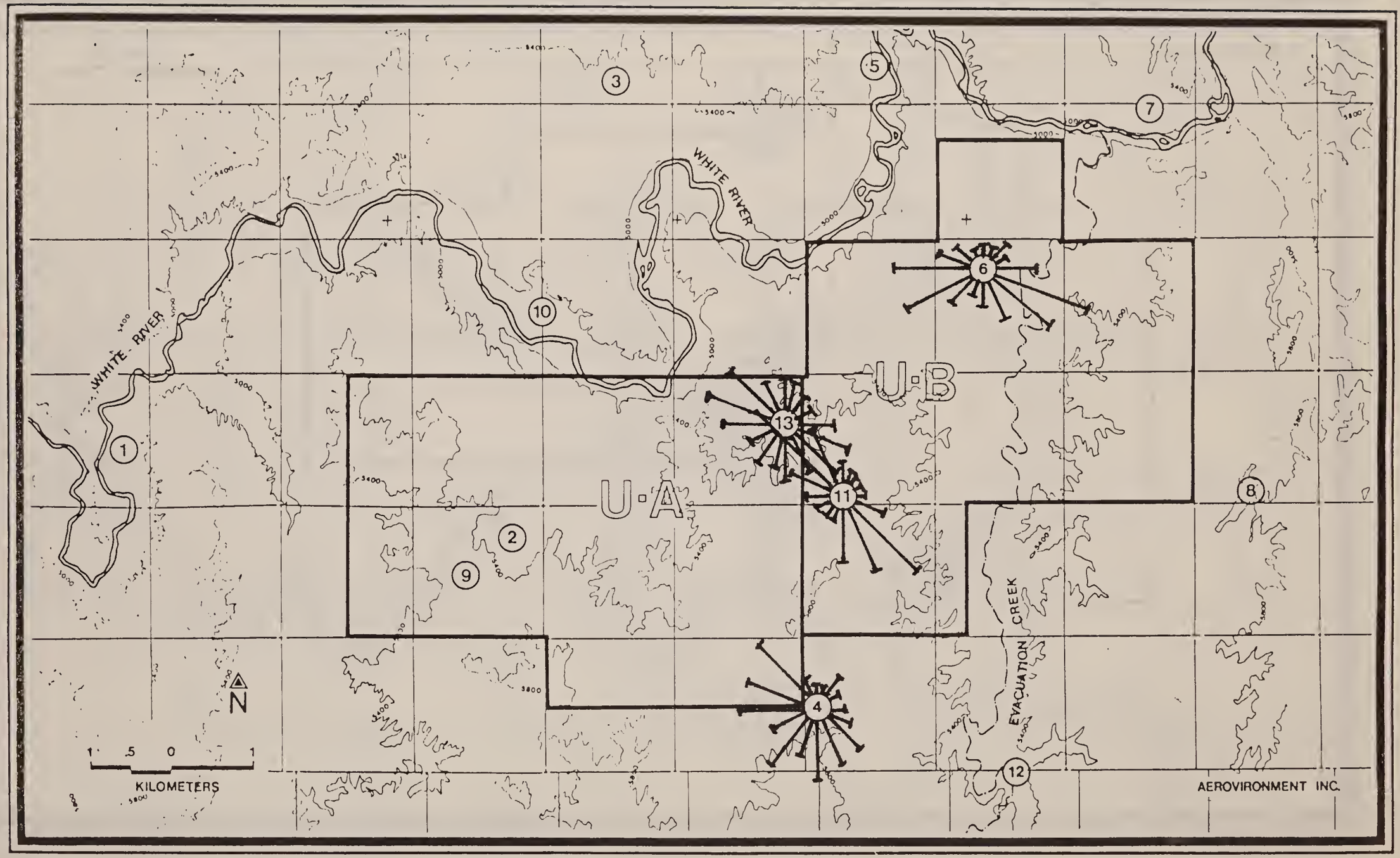
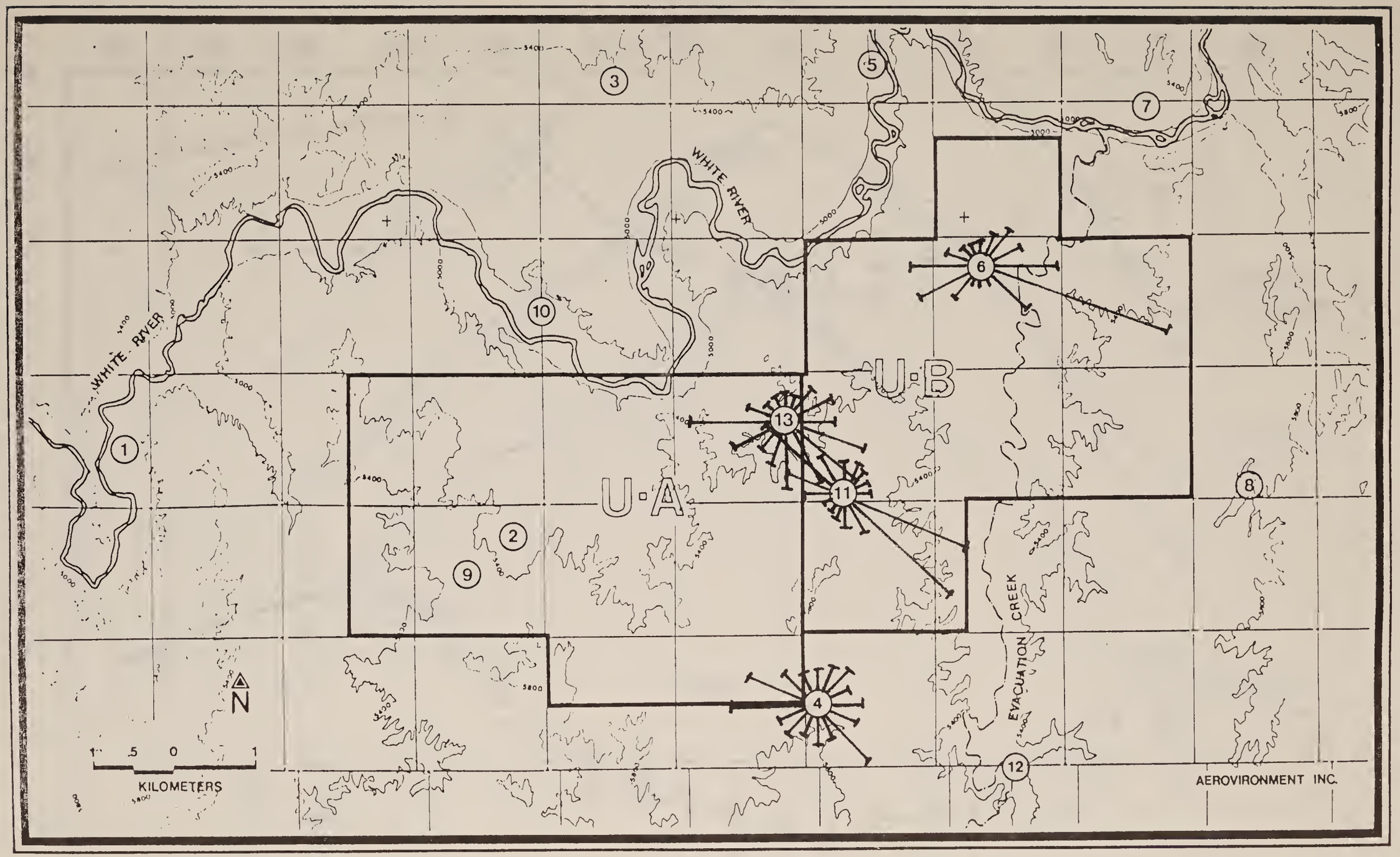


FIGURE 4-41 Directional wind roses at the monitoring stations on the tracts for July 1978. The length of each bar represents the frequency of winds from the direction towards which the bar points.



0 25
%

FIGURE 4-42 Directional wind roses at the monitoring stations on the tracts for October 1978. The length of each bar represents the frequency of winds from the direction towards which the bar points.

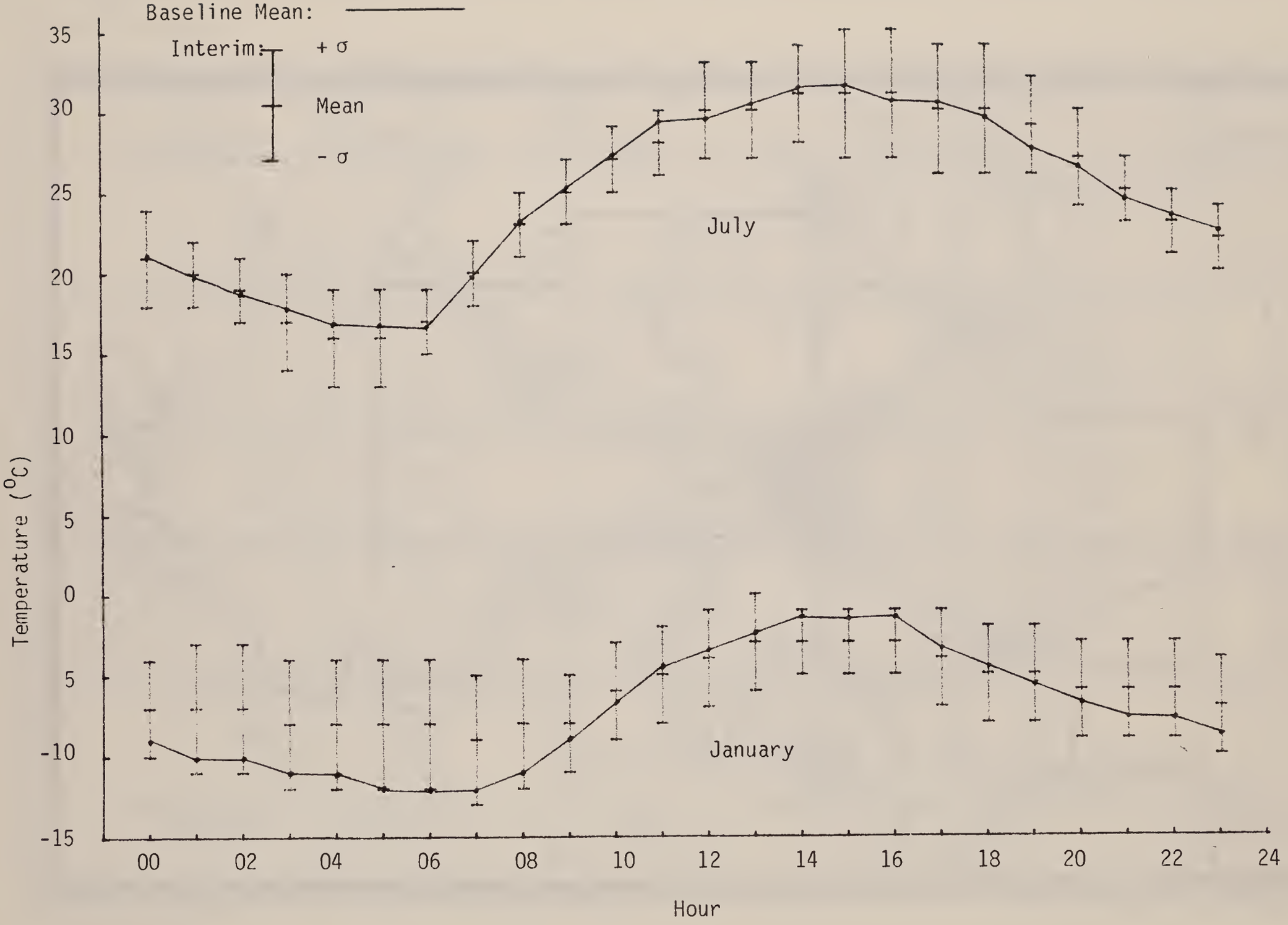


FIGURE 4-43 Diurnal variation of mean temperatures and their standard deviations compared to baseline means at Site A6 during January and July, 1978.

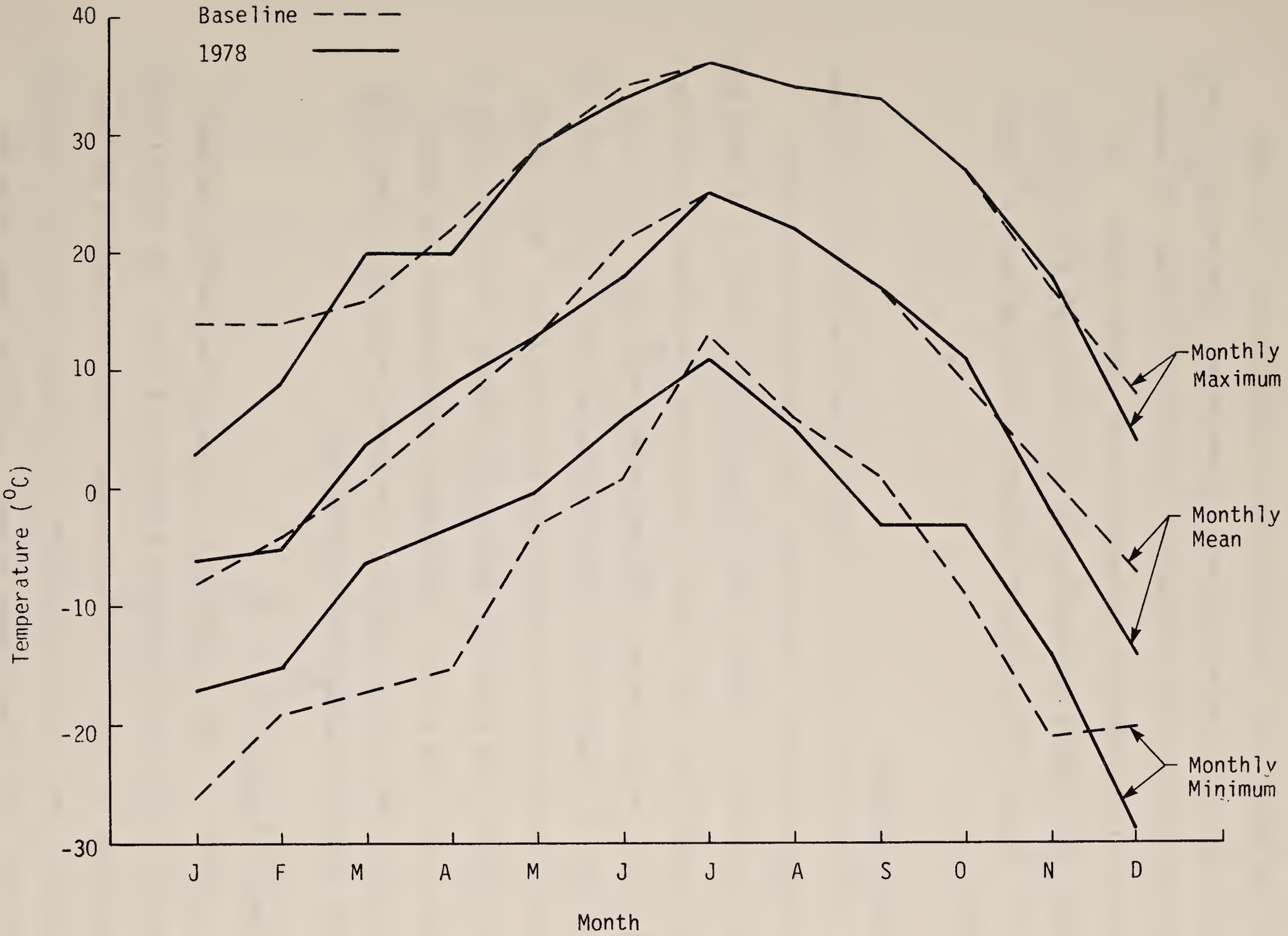


FIGURE 4-44 Monthly mean, maximum and minimum temperatures at Site A6 for 1978 (solid) Compared to baseline (dashed).

for each month in 1978 as compared to the maximum, mean and minimum for the Baseline period. During the winter months of early 1978, above average cloudiness caused the month to have warmer than average temperatures at night but cooler temperatures during the daytime. The summer months of 1978 compared fairly well with the Baseline period. The highest July temperature observed was 36°C during July 1976 (Baseline period) and July 1978 the lowest temperature observed was -29°C during December 1978.

Relative Humidity

On the tracts the diurnal variation of relative humidity is approximately the reciprocal of temperature, indicating that the amount of moisture in the air remains fairly constant during the day. Figures 4-45 and 4-46 show the diurnal trend of the average and standard deviations for a winter month (January 1978) and summer month (July 1978). The storminess of January 1978 with associated moisture is reflected by the high relative humidity values compared to the Baseline. July 1978 was only slightly more humid than the Baseline average. The air is drier in summer than in the winter. The highest average readings are found in winter from 0400 through 0800 MST. The lowest values are found during summer afternoons between 1400 and 1600 MST.

Barometric Pressure

Figure 4-47 gives the maximum, minimum and mean monthly barometric pressure at Site A-6 for both the Baseline and 1978. The highest value observed was 646 mm of Hg during November 1975 (Baseline) and the lowest value of 614 mm of Hg during February 1978 and March and April (Baseline). During the period from October to March the winter storms cause the

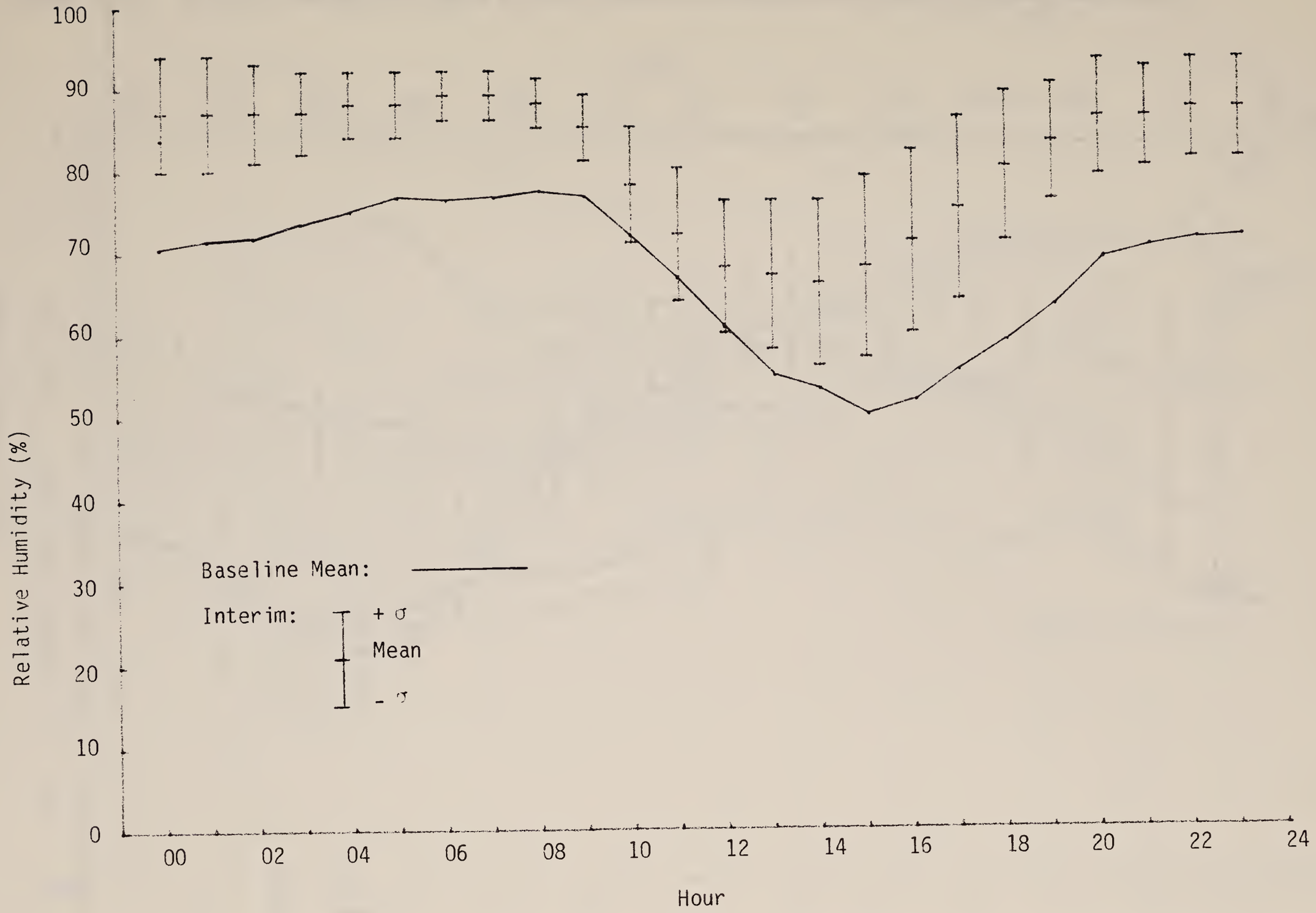


FIGURE 4-45 Diurnal variation of mean relative humidity readings and their standard deviations compared to the baseline means at Site A6 during January 1978.

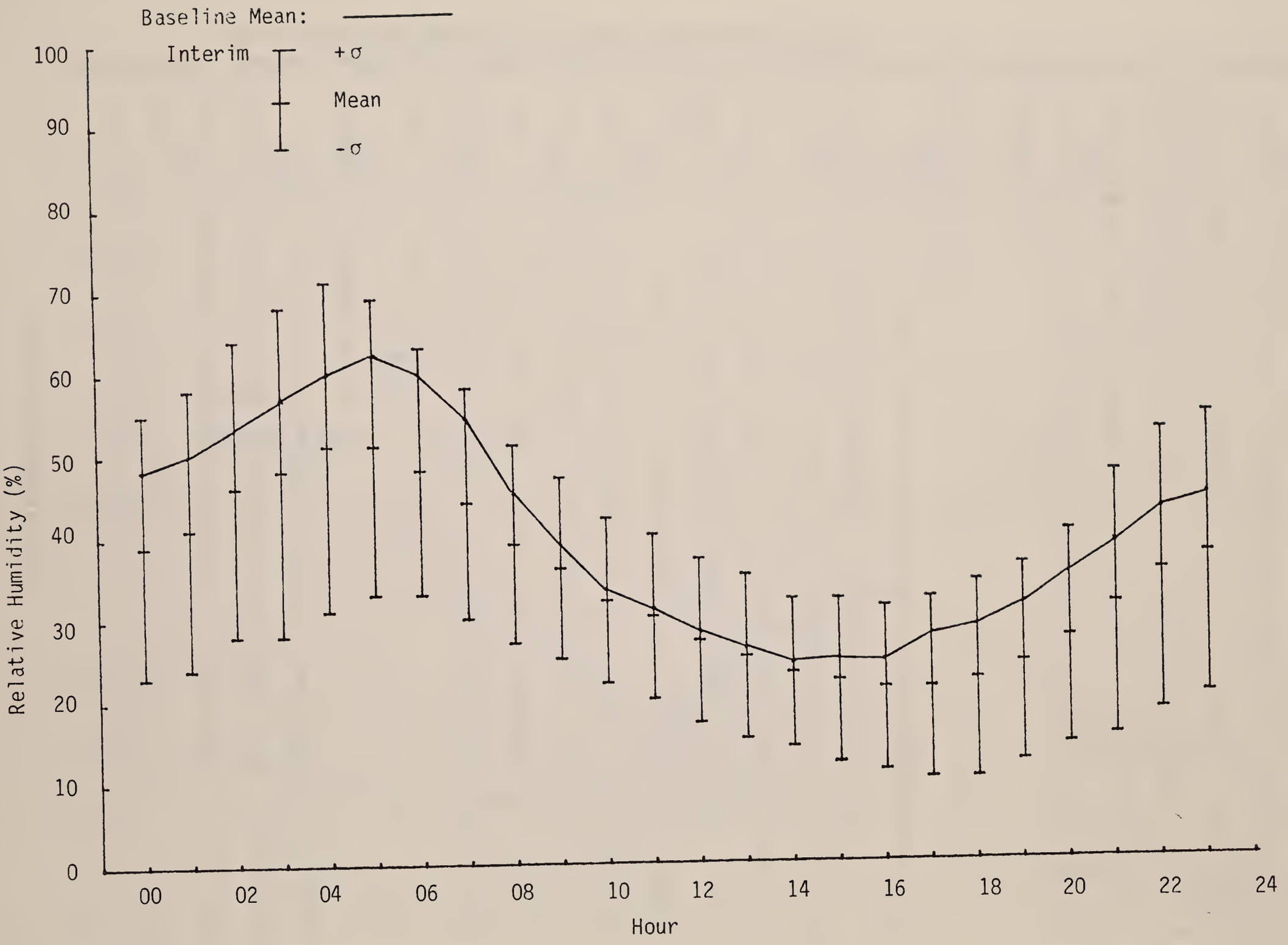


FIGURE 4-46 Diurnal variation of mean relative humidity readings and their standard deviations, compared to the baseline means at Site A6 during July 1978.

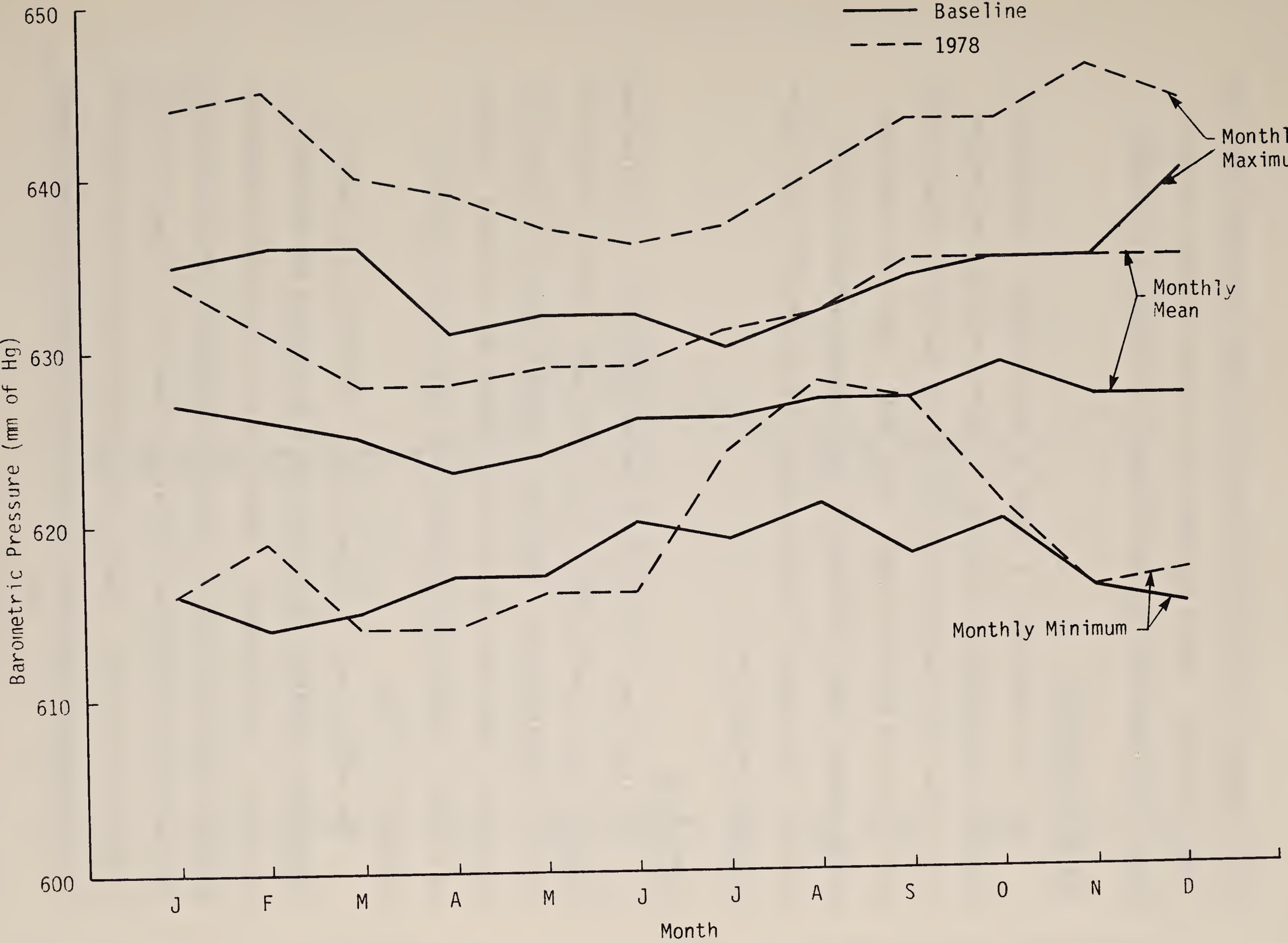


FIGURE 4-47 Monthly mean, maximum and minimum barometric pressure at Site A6 for 1978 (solid) compared to baseline (dashed).

lowest readings, and the basin highs during this time period bring the highest readings. During the summer the air mass systems are much weaker and consequently not much change in the pressure is evident.

Net Solar Radiation

Net solar radiation is a factor to be considered in photochemical processes and atmospheric stability. Figure 4-48 shows the average hourly total solar radiation on tract during the winter (January 1978) and Figure 4-49 shows the summer (July 1978). Again, the cloudiness during January 1978 is reflected by lower average values than the Baseline. More hours of bright sunlight during July 1978 gives higher averages than Baseline.

Diffusivity

The dispersion or dilution of windborne effluents in the atmosphere boundary layer depends greatly on the turbulence intensity of the diffusivity of the atmosphere. There are a number of ways of defining this diffusivity, based both on direct measurements or turbulence as well as on indirect inference of turbulence from other factors related to atmospheric mixing.

One indirect way of estimating this diffusivity is by means of temperature soundings, which can be used to describe the vertical stability of the atmosphere. Knowing the stability, one can then estimate the numberical values of dispersion parameters from experimentally derived stability/diffusion correlation curves, e.g., Pasquill-Gifford curves (Gifford, 1961). However, this approach has in itself certain disadvantages and limitations. The Pasquill-Gifford curves were based

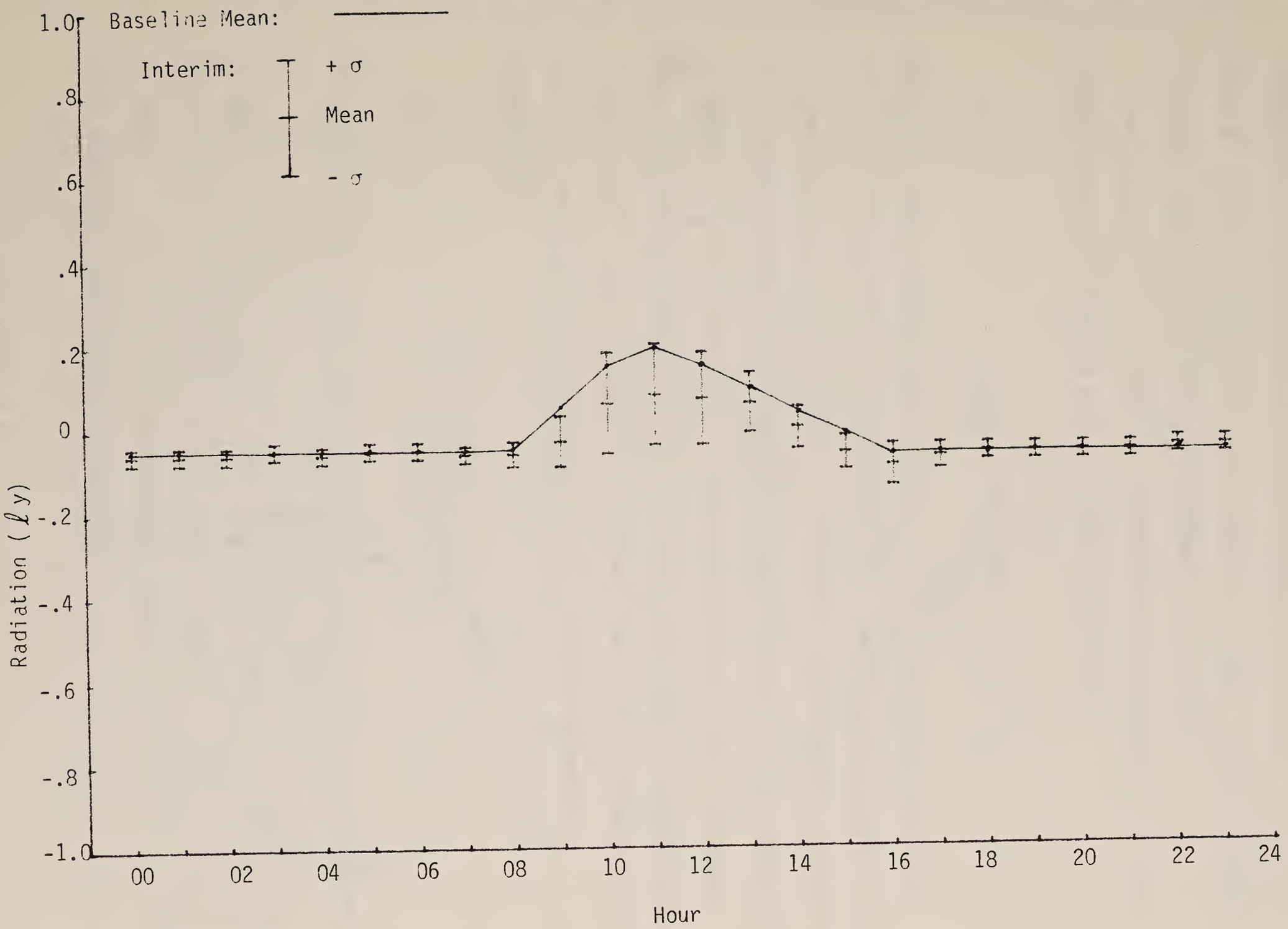


FIGURE 4-48 Diurnal variation of the mean net solar radiation and standard deviations compared to the baseline mean at Site A6 during January 1978.

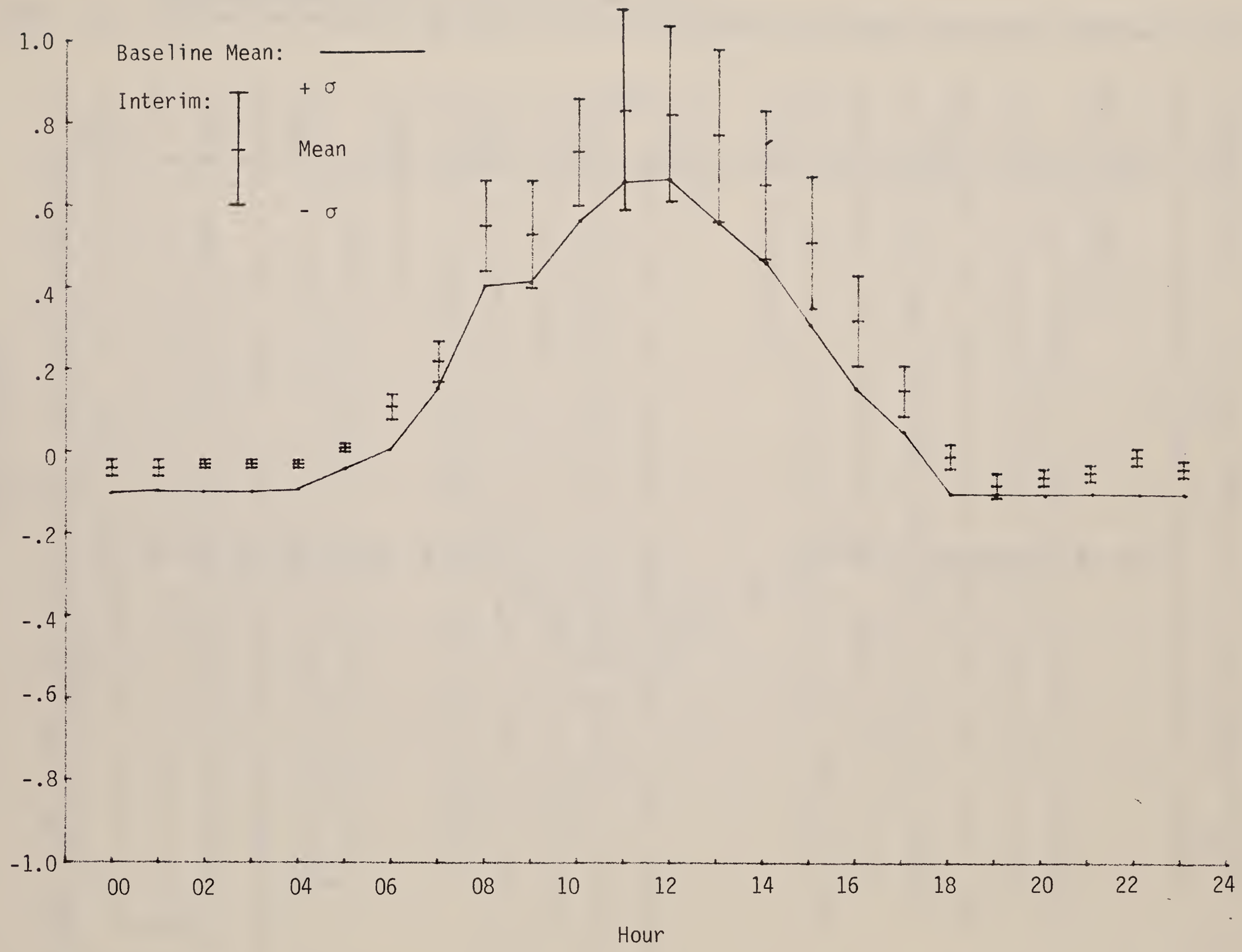


FIGURE 4-49 Diurnal variation of the mean net solar radiation and standard deviations compared to the baseline mean at Site A6 during July 1978.

mostly on ground level concentration measurements made only out to 800 m downwind of a ground level source over smooth, flat terrain. The "Turner Workbook" (Turner, 1970) curves have a similar origin. A more reasonable and direct method is described by MacCready, et al (1974).

The dispersion of a plume is often described mathematically by the Gaussian diffusion equation having the following form:

$$\frac{X}{Q} = \frac{1}{\sigma_y \sigma_z U} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

where X is the surface concentration, Q is the source emission rate, σ_y, σ_z are horizontal and vertical dispersion coefficients, respectively, U is the mean wind speed, and H is the effective stack height. MacCready, et al (1974) show that, at downwind distances in excess of the order of a kilometer, $\sigma_y^2 \sim \sigma_v t$ and $\sigma_z^2 \sim \sigma_w t$ where σ_v and σ_w are the root-mean-square turbulence fluctuations in the lateral wind speed u and the vertical wind speed w and t is the time of plume travel. Using these relations for H = 0, and noting that the location of a receptor is given by x = Ut, one can write

$$\frac{X}{Q} \sim \frac{1}{\left(\sigma_v \sigma_w\right)^{1/2} x}$$

This relationship, with H taken as zero, is valid along the centerline of a plume released aloft, or at the surface for emissions released at the surface (although ground effect makes the constant of proprotionality twice as great in the latter case as in the former). For other cases the decay in X/Q with x is even greater because of the growth of σ_z in the exponential term of the full equation.

For receptors off the plume centerline, an exponential term is included, which includes concentration decay with lateral distance, y, from the centerline:

$$\exp\left(-\frac{ky^2U}{v^x}\right)$$

Its impact will always be such as to decrease the concentration expected.

a. Lateral and vertical wind speed flucuations $(\sigma_v\sigma_w)^{1/2}$

Using this approach, one can have a quantitative characterization of the turbulent intensity, using the measurement of σ_v ($\sigma_v \sim U\sigma$) and of σ_w made continuously at Site A-6. Table 4-37 presents the frequency distribution of the quantity $(\sigma_v\sigma_w)^{1/2}$ for both Baseline and 1978 and shows that the same general trend persisted in both periods. The normal ranges of $\sqrt{\sigma_v\sigma_w}$ were between 0.2 and 0.4. One observes that the values approximately hold also for the Baseline period.

On a diurnal basis low values were generally observed at night and high values in the afternoon. One may notice similar diurnal or seasonal patterns in solar radiation and wind speed. Such correlation illustrates the principle that high downward flux of solar radiation usually induces instability. High winds cause increases in σ_w due to mechanical turbulence in complex terrain, such as the Ua and Ub tracts.

In evaluating the dispersion potential on the tracts, the parameter $\sqrt{\sigma_v\sigma_w}$ should not be considered alone. Equation (2) is only true for ground release or for receptors at plume centerline level for elevated sources. The effect of elevated sources on maximum ground level concentration at receptors at ground level has a strong dependence on the

TABLE 4-37 Relative frequency distribution (%) of $\sqrt{\sigma_v \sigma_w}$ at site A6 for the Baseline and 1978.

BASELINE										
Seasons	$\sqrt{\sigma_v \sigma_w}$ **									Total No. observations
	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	>1.4 of	
Spring	3	31	24	15	14	8	4	1	0	3,159
Summer	0	25	30	19	14	9	3	0	0	3,847
Fall	1	40	27	18	8	4	1	1	0	2,479
*Winter	5	69	22	3	1	0	0	0	0	2,094
1978										
Spring	1	39	24	17	13	6	2	0	0	2,159
Summer	0	30	22	16	18	10	4	0	0	2,010
Fall	1	55	21	15	6	2	1	0	0	2,101
Winter	2	85	10	2	1	0	0	0	0	1,478

*Based on the year 1976 alone
**Each interval of $\sqrt{\sigma_v \sigma_w}$ spans 0.2 m/s and commences with the value shown.

"effective stack height." Effective stack height is a combination of the physical stack height and plume rise. When plume rise is under proper perspective, an evaluation of the overall dispersion potential for elevated sources is meaningful.

b. Wind direction fluctuation, σ_θ

Consistent with the position that σ_v and σ_w depict turbulence intensity better than vertical atmospheric stability does as defined by temperature soundings or other methods, one can also follow the general convention and categorize turbulence intensity into different "stability" (or better, "diffusion") classes. Using σ_θ data at Site A-6, the frequency distribution of different "stability" classes is computed and presented in Table 4-38. The classification scheme used follows that in Atomic Energy Safety Guide 23 (AEC, 1972) and appears in Table 4-39. This exercise is done to emulate the classical Pasquill-Gifford stability schemes for those who are accustomed to and are more comfortable with this type of classification. It is done also for those who will use σ_θ in their model instead of $\sqrt{\sigma_v \sigma_w}$. Again, it should be stressed that the Pasquill-Gifford stability curves are intended only for flat or smoothly rolling terrain.

When the whole year is considered, stability classes D and E are most prevalent on the tracts. Data collected at Site A-6 shows that variability in stability classes with atmospheric conditions is greatest in winter and the overall pattern is still tending toward a stable atmosphere. One should also note the similarity in trends in σ_θ and $\sqrt{\sigma_v \sigma_w}$; they both measured approximately the same thing. Comparison with the Baseline values shows no significant changes.

TABLE 4-38 Relative frequency distribution (%) of stability classes at Site A6 for the Baseline and Interim Periods. Table 6 defines the classes A through F.

Period	Season	Stability Classes						Total # of obs.
		A	B	C	D	E	F	
Baseline	Winter	.7	.8	6.2	27.2	46.8	18.3	2,204
	Spring	.3	.5	5.4	29.3	58.4	6.1	2,208
	Summer	.0	.0	3.1	36.5	54.6	5.8	2,117
	Fall	.0	.4	6.2	27.2	46.4	19.8	2,182
1978	Winter	.0	.3	5.3	29.8	53.2	11.5	1,904
	Spring	.2	1.9	10.7	28.8	50.0	8.5	2,207
	Summer	.1	1.6	12.6	32.3	42.0	6.5	2,010
	Fall	.0	.7	13.3	29.4	41.7	14.9	2,171

TABLE 4-39 Classification of atmospheric stability.

Stability Classification	Pasquill Categories	σ_θ*
Extremely unstable	A	25.0^o
Moderately unstable	B	20.0^o
Slightly unstable	C	15.0^o
Neutral	D	10.0^o
Slightly stable	E	5.0^o
Moderately or very stable	F	2.5^o

Source: Atomic Energy Safety Guide 23 (AEC, 1972)

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*Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to one hour. The values shown are averages for each stability classification.

c. Temperature difference, ΔT

As mentioned earlier, a complete dispersion picture must also include the effect of plume rise. The total effect of all influencing parameters on dispersion will be discussed below. Two meteorological parameters greatly influence the height of a plume; namely, the atmospheric stability and wind speed. Vertical atmospheric stability can be best defined by ΔT data. In equations derived by Briggs (1974) for calculating plume height, only three atmospheric stability classes are needed. The classification scheme is listed in Table 4-40.

Figures 4-50 and 4-51 present the diurnal variation of ΔT collected at Site A-6 for two months, January (winter) and July (summer) 1978. Note that very stable or slightly stable atmospheric conditions prevailed in early morning and evening during July. In the afternoon neutral or unstable conditions were a general rule. Because of the almost continuous cloudiness throughout the month of January, the development of a strong nocturnal stability was prohibited. Thus, there was only a small diurnal variation in the mean ΔT and the stability was almost always slightly stable or neutral throughout the day.

The frequency distribution of stabilities based on ΔT appears in Table 4-41 which shows the very stable condition occurred more frequently in the summer and fall, whereas unstable or neutral activities occurred more often in the spring and fall. One thing that should be mentioned is the total accuracy of the ΔT system at Site A-6. The system for the Interim year measures ΔT to within $\pm$ 0.1^{o}C/20 meters over the measurement interval. Accuracy was below this level in the Baseline period; hence, no comparison of the ΔT data is attempted for these two periods.

TABLE 4-40 ΔT stability scheme.

Stability	ΔT ($^{o}C/100m$)
1. Unstable and Neutral	<-0.5
2. Slightly Stable	-0.5 to 1.5
3. Very Stable	>1.5

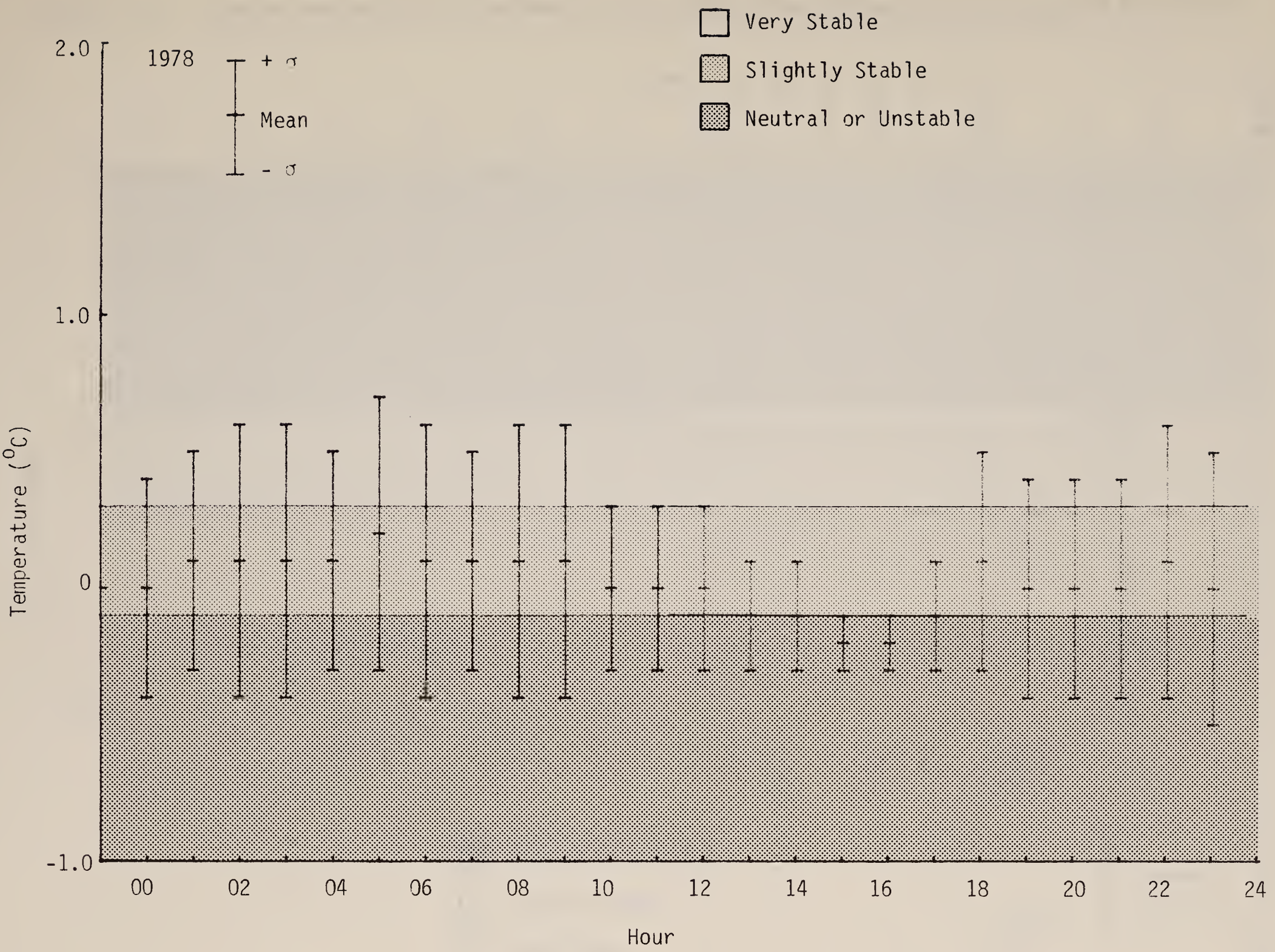


FIGURE 4-50 Diurnal variations of the mean ΔT and standard deviations at Site A6 during January 1978.

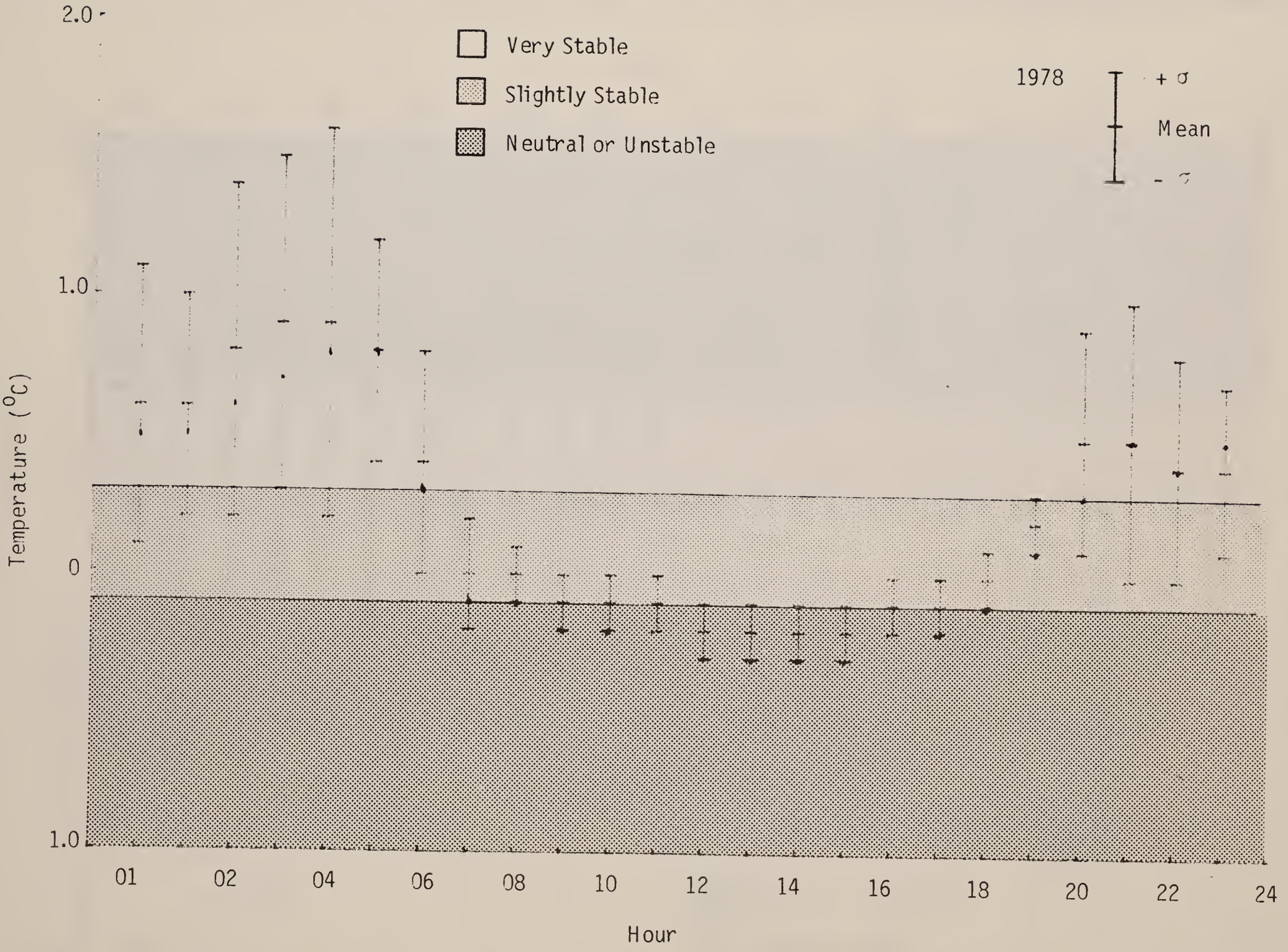


FIGURE 4-51 Diurnal variations of the mean ΔT and standard deviations at Site A6 during July 1978.

TABLE 4-41 Relative frequency distribution (%) of ΔT at Site A6 for 1978.

Season	Stablility (ΔT in $^{o}C/100m$)			Total No. of Observations
	Unstable or Neutral (<-0.5)	Slightly Stable (-0.5 to 1.5)	Very Stable (>1.5)	
Winter	40	30	30	2,134
Spring	42	42	16	2,207
Summer	31	37	33	2,162
Fall	45	22	33	2,184
All Year	40	33	28	8,687

It has been found that high wind speed coupled with high turbulent intensity produces an adverse condition, and the distance to maximum X/Q is shortest in this case. However, these conditions did not occur at Site A-6.

Also, low wind speed with very stable atmosphere is also adverse to dispersion. The distance to maximum X/Q becomes shorter the more stable the atmospheric conditions.

Therefore, for elevated sources on the Ua and Ub tracts most adverse conditions can be characterized by these two combinations of meteorological parameters.

Joint Frequency Distributions

To facilitate in pinpointing the approximate time of the year in which the adverse combinations discussed above occur, joint frequency distributions for wind speed, wind direction, diffusivity and stability, were constructed for Site A-6 for 1978. The joint frequency distributions were categorized into vertical atmospheric stability classes, as defined by ΔT, and turbulence intensity (or diffusion) classes as defined by σ_θ. The classification schemes are shown in Tables 4-40 and 4-39, respectively. This type of information, with some modifications, is useful also as input into many climatological dispersion models, such as the CDM model of EPA, to compute annual average of a particular pollutant.

Examining the entire set of joint frequency distributions, one finds the combination of very stable atmosphere with low wind speed (<3.5 m/s) occurred 35.5% of the time in the entire year, with such occurrences most

frequent (49.6%) in the summer. Table 4-42 shows the relative frequencies of such occurrences by seasons and in the entire year.

The other condition classified as adverse to diffusion identified above was high wind speed coupled with high turbulence intensity. The combination of high wind speed (8 m/s or greater) and high turbulence intensity (A or B, σ_θ class) did not occur at all on the tracts.

TABLE 4-42 Relative frequency (%) of low wind speed (3.5 m/s) combined with very stable atmosphere within each season and for 1978 at Site A6.

Season	Frequency (%)	Total Observations
Winter	31.88	1,827
Spring	21.83	1,444
Summer	49.64	1,245
Fall	38.45	1,840
All Year	35.45	6,356

REFERENCES

AeroVironment Inc. (1978): Air resources program lease suspension period, oil shale tracts Ua and Ub. (AV FR-8012, AeroVironment Inc., February 1978.)

AeroVironment Inc. (1978): Quality assurance plan for air resources monitoring, oil shale lease tracts Ua/Ub. (AV QA-8047, AeroVironment Inc., April 1978).

Atomic Energy Commission (1972): Safety guides for water cooled nuclear power plants. USAEC, Division of Reactor Standards, Washington, D.C. 20545. Safety Guide Number 23: On-site Meteorological Programs.

Briggs, G.A. (1974): Diffusion estimation for small emissions. USAEC Report. ATDL-106NOAA.

Gifford, F.A. (1961): Uses of routine meteorological observation of estimating atmospheric dispersion. Nuclear safety, 2 (4), 47-51.

MacCready, P.B., Jr., L.B. Baboolal, and P.B.S. Lissaman (1974): Diffusion and turbulence aloft over complex terrain. Paper presented at the AMS Symposium on Atmospheric Diffusion and Air Pollution, 9-13 September, Santa Barbara, CA. (AV TP-311, AeroVironment Inc., Pasadena, CA).

Newell, R.E. and M. Wu (1973): A pilot study of concomitant changes in total ozone and atmospheric general circulation. Quarterly Journal of the Royal Meteorological Society, 104, October 1973.

Singh, H.B.; F.L. Ludwig; and W.B. Johnson (1978): "Tropospheric Ozone Concentrations and Variabilities in Clean Remote Atmospheres. Atmospheric Environment, 12, 2185-2196.

Turner, D.B. (1970): Workbook of atmospheric dispersion estimates. Environmental Protection Agency, Publication No. AP-46.

4.3 BIOLOGICAL RESOURCES

Biological resources monitoring for the two year Environmental Baseline Monitoring Program was completed during January of 1977. At that time an Interim Monitoring Program was implemented. This section discusses the work accomplished during 1978 as part of this program.

Tracts Ua and Ub are within the eastern portion of the Uintah Basin, a broad, northwest-facing asymmetric basin on the northeastern edge of the Colorado Plateau (Figure 4-52). The Uintah Basin overlies alluvial sediments of a prehistoric depositional lake basin. Major land features bordering the basin are the Uinta Mountains on the north, the Wasatch Range on the west, the Roan and Book Cliffs on the south, and the highlands associated with the subsurface Douglas Creek Arch along the eastern edge.

The Green River, flowing generally southwestward, is the major drainage within the basin. The majority of its water comes from the westward-flowing White River, its headwaters in the White River Plateau of Colorado and the eastward-flowing Duchesne River, its headwaters in the Uinta Mountains.

Tracts Ua and Ub are bounded by the White River to the north, Hell's Hole Canyon to the east, upland areas of elevations between 1829 m and 1890 m (6000-6200 ft.) to the south, and Asphalt Wash to the west. The region near the tracts, including the area extending southward to the Roan Cliffs and westward to the Green River, is a gently north-sloping, highly dissected plateau characterized by steep-walled canyons with ephemeral streams or dry washes.

Within the tracts the landscape is composed of a series of north-south-trending valleys separated by narrow, elongated mesas. Thirty-three

—·— PHYSIOGRAPHIC BOUNDARY

INDEX MAP

SCALE IN MILES

PHYSIOGRAPHIC MAP OF THE UINTA BASIN REGION

FIGURE 4-52
Page 4-157

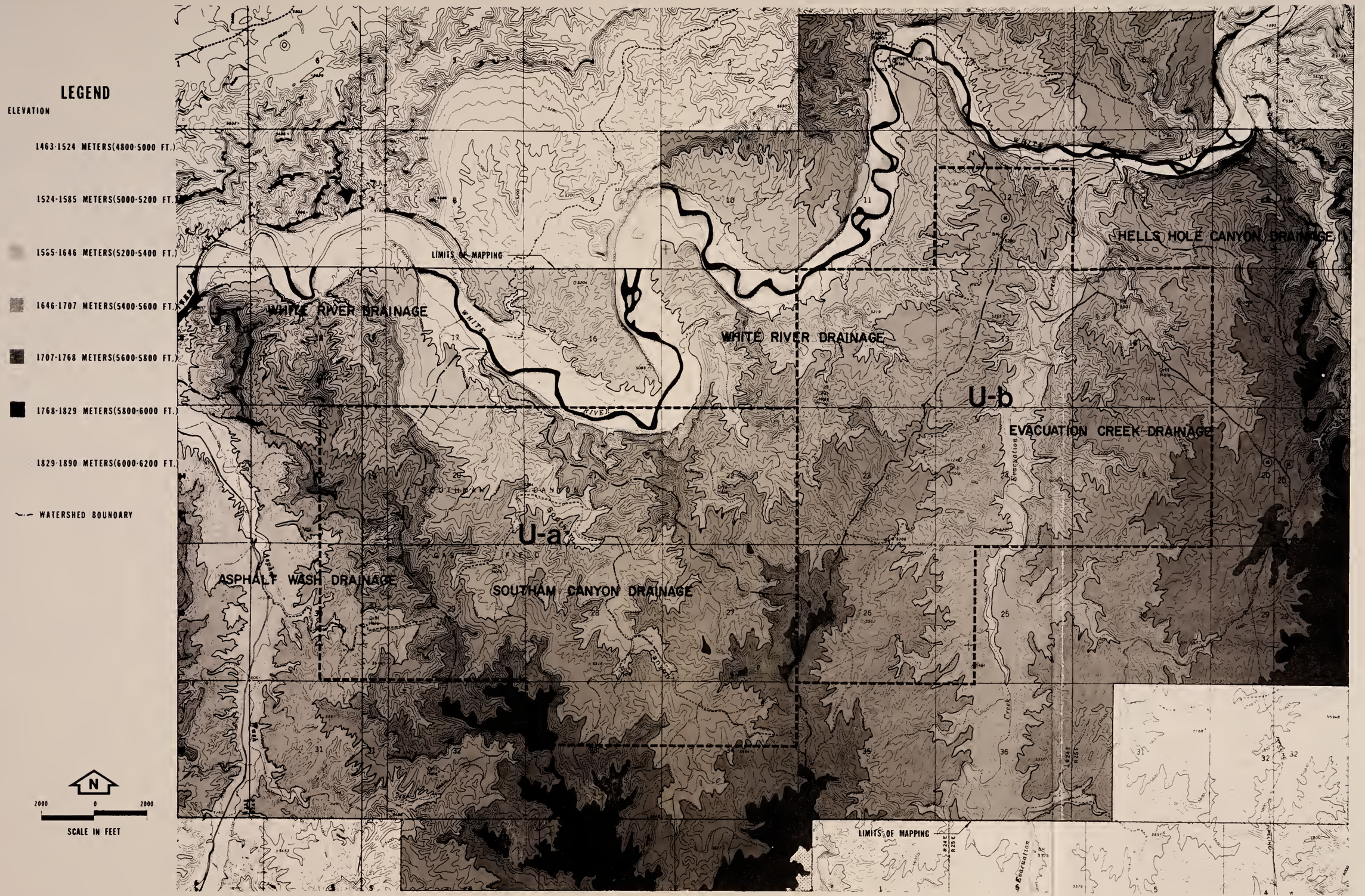
percent of the tracts proper drains into Evacuation Creek, 31 percent is in the Southam Canyon drainage, 30 percent drains directly into the White River, and 6 percent is in the Asphalt Wash drainage. Elevations range from 1500 m to 1890 m (4920 ft. to 6200 ft.) (Figure 4-53).

The White River is the only perennial stream running through the tracts, although Evacuation Creek contains surface flow for several months of the year, mainly from brackish and, in some places, poisonous ground water discharge from the Bird's Nest aquifer. Southam Canyon, Asphalt Wash, and tributaries of Evacuation Creek and the White River are all ephemeral.

The soils along the flood plain of the White River and along smaller drainageways throughout the area have formed in alluvium. The alluvium along the White River has come from a wide range of transported materials, whereas in the smaller drainages the materials are largely deep, sandy loams and channery, sandy loams derived locally from the Uinta and Green River formations. The parent material for the upland soils is also the Uinta and Green River formations, over which the soils are shallow or very shallow.

The tracts are in the Colorado Plateau physiographic province, distinguished by the nearly level bedrock and the numerous canyons and generally high elevation. Most of the area is between 1520 m and 1850 m (5000 ft. and 6000 ft.) above sea level. The topography of the area is sloping to steep slopes ranging from about 5% to over 60%. The western part of the tracts is characterized by numerous nearly vertical sandstone cliffs. The eastern part of the tracts, east of Evacuation Creek, has more rolling topography and fewer sandstone cliffs.

Shrubs, forbs and grasses are the dominant vegetation over much of the area. Juniper trees are common at higher elevations above



DRAINAGE BASIN SHADED RELIEF MAP

FIGURE 4-53
Page 4-159

1650 m (5400 ft.) west of Evacuation Creek, with scattered pinon pine at the highest elevations. There is an open stand of large cottonwood trees along the White River valley, and young willows and tamarisk grow in the most recent deposits. Big sagebrush is the dominant vegetation along numerous drainageways throughout the area. Shadscale, black sage, cheatgrass, Indian ricegrass, squirreltail, and some forbs are common on shallow upland soils. Greasewood and shadscale are common in alkali-affected areas.

Plant-available moisture is the most important factor in the distribution of vegetation types in the arid west, and soil characteristics are one of the important factors that determine plant available moisture. As a result, the distribution of vegetation types often corresponds to the distribution of soil types. On the tracts, where vegetation-pattern and soil-type distribution coincide, it is usually a function of soil moisture.

Greasewood vegetation occurs exclusively on the D soils at the site. D soils are the deep, sandy loam soils forming in alluvium. They occur in the relatively narrow drainages below steeply sloping soils and rock outcrops. The soil has a relatively high water-holding capacity. The correlation between areas of D soil and areas of greasewood vegetation is the closest of any of the soil-vegetation relationships at the site.

Riparian vegetation, as the name implies, is found only in areas adjacent to water and on moist soils. The soils of the site that are moist enough to sustain this type of vegetation are W soils and D soils. The W soils are deep, imperfectly drained and form in silty alluvium

adjacent to the flood plain of the White River. All of the W soils mapped at the site support riparian vegetation. Riparian vegetation also occurs along Evacuation Creek where D soils are moist enough.

The upland soils at the site are similar to one another but support a variety of vegetation types. The juniper type is found at the high elevations on the thin, sandy soils--As, Bs and F. These are shallow and very shallow sands, sandy loams, or loams. The eastern limits of juniper roughly coincide with the limits of these soils along the west side of Evacuation Creek. However, the same soils extend beyond the limits of the juniper type because juniper is limited by its altitudinal requirements. The thin sandy soils that are below the juniper-vegetation limits to the north and to the west are dominated by big sagebrush.

The A and B soils have formed on the Green River Formation. Being very shallow loam soils, they are less sandy than the upland soils found on the Uinta Formation. The vegetation on these soils is exclusively the shadscale-black sagebrush type. The shadscale-black sagebrush types is not limited to soils A and B, but also dominates the sandy soils (As, Bs, and F) that occur north of the White River.

Plant communities on the tracts are sagebrush-greasewood, juniper, shadscale, and riparian (Figure 4-54). The dominant shrubs in the sagebrush-greasewood community are big safebrush (Artemisia tridentata), greasewood (Sarcobatus vermiculatus), and shadscale (Atriplex confertifolia). Other major shrubs associated with the community include horsebrush (Tetradymia) spp.), hop sage (Grayia spinosa), and black sage (Artemisia nova). The dominant herbaceous species persisting into fall

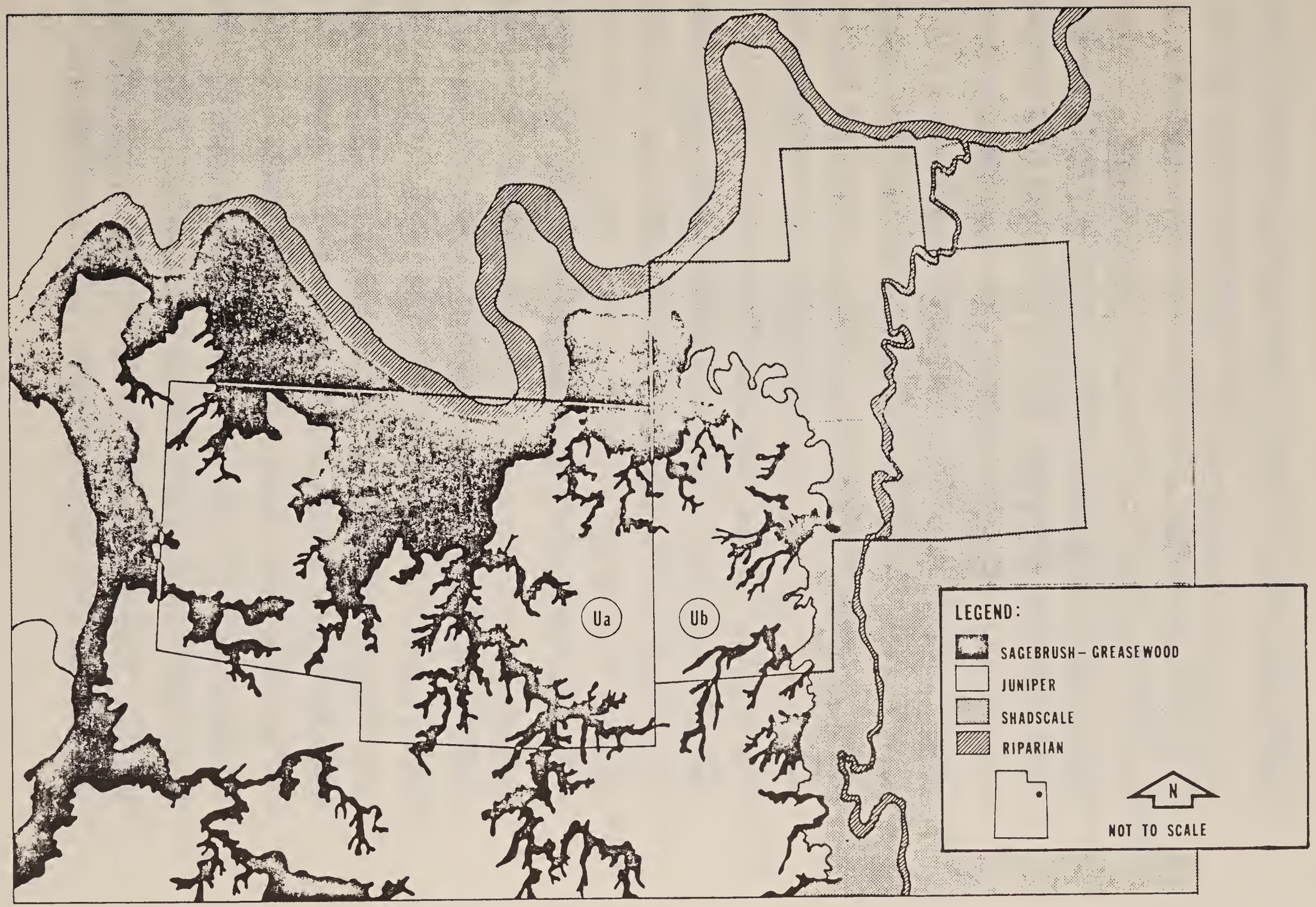


FIGURE 4-54 Vegetation types on the Utah Oil Shale Tracts (After map by VTN, Inc., 1977).

include Russian thistle (Salsola kali), snake weed (Gutierrezia sarothrae), and rabbitbrush (Chrysothamnus spp.) Both Russian thistle and rabbitbrush are indicative of heavily grazed if not overgrazed vegetation. Chrysopsis (Chrysopsis spp.), fleabane (Erigeron engelmánnii), prickly pear (Opuntia spp.), and winterfat (Eurotia lanata) are other major species.

Cheatgrass (Bromus tectorum) is the dominant grass in the spring. Indian ricegrass (Oryzopsis hymenoides), needle-and-thread grass (Stripa comata), and Galleta grass (Hilaria jamesii) are subdominant grasses which persit into fall and represent the dominant fall grasses. Cheatgrass and needle-and-thread grass provide good forage while young, but poor forage when mature. The borage family (Boraginaceae spp.) and mustard family (Cruciferae spp.) provided the dominant spring herbs. Mentzelia (Mentzelia albicaulis), squirrel tail grass (Sitanion hystrix), Cleome (Cleome lutea), and red sage (Kochia americana) are other major species appearing in the spring.

The juniper community is dominated by Utah juniper (Juniperus osteosperma). Only four pinon pines (Pinus edulus) were encountered during the field sampling. Black sage and to a lesser extent shadscale and big sage are the major shrubs. Snakeweed, spurge (Euphorbia spp.) while buckwheat (Eriogonum spp.), rabbitbrush, and fleabane are the major herbaceous species persisting into fall.

Galleta grass and Indian rice grass are the dominant grasses in the spring and persist into fall. Spring herbs are dominated by the borage family, wildbuckwheat, red sage, and sweet vetch (Hedysarum boreale). Other spring species include pepper grass (Lepidium montanum) and other species in the mustard family, needle-and-thread grass,

Kentucky bluegrass (Poa pratensis), cheatgrass, phlox (Phlox hoodii), and lambs quarter (Chenopodium album).

The dominant shrubs of the shadscale community are shadscale and big sage. The other major shrubs include black sage, greasewood, and to a lesser extent hop sage and horsebrush (Tetradymia spinosa). Herbaceous species persisting into fall include rabbitbrush, snakeweed, halogeton (Halogeton glomeratus), milk vetch (Astragalus spp.), and Russian thistle. As in the sagebrush-greasewood community, the rabbitbrush, halogeton, and Russian thistle are indicative of heavy grazing pressure. Indian rice grass is the dominant fall grass, with needle-and-thread grass and Galleta grass represented to a lesser extent.

Cheatgrass dominates the spring growth, with blue mustard (Chorispora tenella) and other species in the mustard family the dominant herbs. Other spring species include wild buckwheat, Indian rice grass, squirrel tail grass, stickseed (Lappula redowskii), and other species of the borage family; and globe mallo (Sphaeralcea coccinea), Galleta grass, Metzelia, and onion (Alluim spp.).

Cottonwood (Populus fremontii) dominate the riparian community along the White River, with saltcedar (Tamarix pentandra) the dominant understory shrub. In the riparian area along Evacuation Creek, saltcedar and greasewood are the dominant shrubs. Horsetail (Equisetum arvense), rabbitbrush (Chrysothamnus viscidiflorus and Chrysothamnus nauseousus) and wire rush (Juncus balticus) are also dominant understory plants. Other major shrubs include greasewood, willow (Salix exigua), saltbrush (Atriplex patula), and big sage. Russian thistle, yellow sweet clover, and snakeweed are the major herbaceous species persisting into the fall.

Saltgrass (Distichlis stricta) is the dominant grass in the fall, with western wheatgrass (Agropyron smithii) and to a lesser extent muhly (Muhlenbergia asperifolia) and Kentucky bluegrass the other major grasses persisting into the fall. Spring growth is dominated by cheatgrass. Pepper grass (Lepidium perfoliatum) and other species of the mustard family, yellow sweet clover, saltgrass, and western wheatgrass are the major spring plants. Other herbs and grasses occurring in the riparian community include Kochia (Kochia spp.), stickseed and other species of the borage family, Kentucky bluegrass, blue mustard, smother weed (Bassia hyssopifolia), six weeks fescue (Festuca octoflora), sand bur (Cenchrus pauciflorus), snakeweed, the root parasite bastard toadflex (Comandra pallida), ragweed (Ambrosia psilostachya), proverty weed (Iva axillaris), alkalai sacaton (Sporobolus airoides), sagebrush (Artemisia ludoviciana), and reed (Phragmites communis).

The major factors determining the distribution, composition and structure of the plant communities are primarily soils and available water. The cottonwood-dominated riparian community is restricted to the area along the White River where available water is abundant. The juniper community occurs in the higher elevations where soils are very thin and poorly formed.

The sagebrush-greasewood and shadscale communities occur in the areas of relatively low relief, with the sagebrush-greasewood community occurring in the swale areas with relatively deeper soils. The major plant species occurring in both communities are almost identical; however, the dominance of different species distinguishes one community from the other. The shadscale community is dominated by shadscale and

big sage, which have shallow root systems relative to greasewood, a co-dominant with shadscale and big sage in the sagebrush-greasewood community.

Of the major shrub species, shadscale and big sage are the dominant species in the sagebrush-greasewood and shadscale communities and are the major shrubs in the juniper community. Black sage is a major shrub in all three communities relative to big sage and shadscale, but it is the dominant understory shrub in the juniper community.

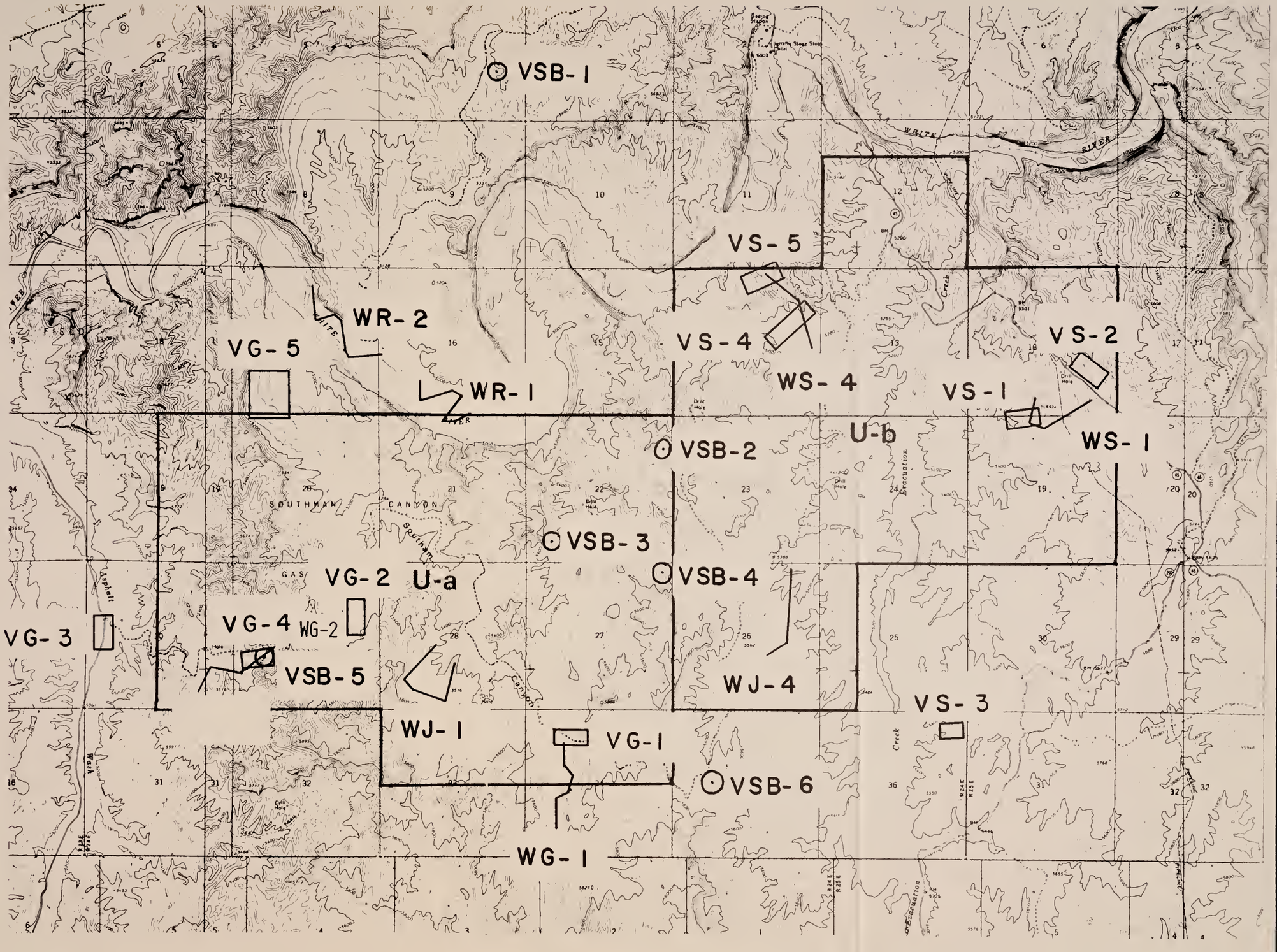
Indian rice grass is a dominant fall grass in all three communities. Galleta grass is a fall co-dominant in the juniper and shadscale comunities, and needle-and-thread grass is a fall co-dominant in the shadscale and sagebrush-greasewood communities. In spring the dominant grasses in the juniper community are Indian rice grass and Galleta grass; while cheatgrass is the overwhelmingly dominant grass in the sagebrush-greasewood, shadscale, and riparian communities.

Rabbitbrush is a major herbaceous species in all four communities, and snakeweed is a common major herbaceous species in all but the riparian community. Russian thistle is a major plant in the shadscale, sagebrush-greasewood and riparian communities, but is rare in the juniper community.

Figure 4-55 shows the locations of the monitoring sites used for vegetation and animal monitoring activities.

FIGURE 26

VEGETATION/VERTEBRATES
MONITORING SITES



LEGEND

- □ = VEGETATION - GREASEWOOD, JUNIPER, SHADSCALE
- ⌇ = WILDLIFE
- ⊙ = VEGETATION - SAGEBRUSH

1 0 1
SCALE IN MILES

4.3.1 Vegetation

The following material discusses the monitoring work done as part of the Interim Monitoring Program during 1978. Dr. Cyrus McKell did the work under contract to WRSP.

4.3.1.1 Objectives. The primary objectives of the vegetation monitoring work are to maintain continuity of data collection on key parameters, determine trends, develop supportive vegetation data for animal monitoring results interpretation, and to explore "control" versus "treatment" systems of monitoring oil shale development impacts.

4.3.1.2 Methods. The approach used to reach the objectives of the monitoring effort was to measure plant productivity and stem growth, and visually inspect the condition of the vegetation.

Two periods of productivity monitoring were emphasized: June, when annual plant species were at their peak of production, and October, when the majority of shrubs had achieved their final amount of growth in stem leader and seed production.

In June 1978 five study areas were visited in each of the four vegetation types that were monitored during the Baseline study. In each of the study areas 10 plant biomass quadrats were located and sampled. The quadrat area harvested was .25 meter. Plants were measured for height and then clipped at ground level and returned to the laboratory for drying and recording of weight.

There was no change in methodology for the stem growth measurements in 1978 from those used in the three previous years of this study. The current growth of 20 stems from 20 individual plants in each of six

sampling sites was measured. Each measurement was from the previous bud scale scar to the tip of the new growth (Figure 4-56).

As discussed in the original methodology and again in the 1977 Progress Report, a plant growth parameter is needed that will characterize plant response to growing conditions in a current year. Although overall height of a shrub plant community does not change materially from year to year, individual stem length has been observed to be long or short depending on favorable growing conditions during the year.

One problem in considering stem length as an index of site favorability is that of having an assessment of variability from site to site and from plant to plant. Such is the purpose of the present sampling-measurement study --to assess the variability problem prior to development of the oil shale tracts. Two sampling locations were chosen for their proximity to the proposed research site, and four locations were chosen for their distance in four directions away from the retort site.

4.3.1.3 Data Summary. During the 1978 growing season weather was more favorable for plant growth than in the 1977 growing season (Table 4-43). The main reason for the improved favorability in 1978 apparently was the greater amount of moisture received in the winter, especially the months of January and March. Following this moist period, May through July were dry which appeared to limit plant development and seed maturity of late summer maturing perennial species. In this regard, we noted the absence of seed production of rabbitbrush plants on the tracts as well as in other areas of Utah. Sagebrush seed production varied according to specific location, but rabbitbrush seed production appeared to be near zero.

FIGURE 4-56

Measuring the length of current year's growth of a sagebrush stem. Measurement is from pervious year's budscale scars to tip of a nonflowering stem.

Table 4-43 A comparison of precipitation for 1976, 1977 and 1978 for sites in the Utah Oil Shale Tracts accumulated according to plant growth year (October through September).

	Year		
Month	1976*	1977**	1978*
October	1.47	.10	.96
November	.37	0	1.58
December	.66	T	.30
January	.22	.30	1.51
February	.39	.65	.35
March	1.18	.77	1.00
April	.75	1.30	1.45
May	1.44	.37	.15
June	1.20	.04	0
July	.47	1.18	0
August	.66	1.22	.47
September	.98	.68	.34
Total	9.79	6.61	8.11

* Precipitation recorded at retort site RS-13

** Revegetation site

Annual vegetation which depended on precipitation during the spring growing season for maturity produced moderately good biomass yield. Less favorable yields were noted on late summer maturing species of shrubs, forbs and Russian thistle (Salsola kali).

The productivity results for each of the vegetation types were summarized and appear in the following tables.

A. Shadscale Sagebrush Vegetation Type

Annual plants in this type were short and produced only a limited amount of biomass in 1978 (Table 4-44). As in previous years, the dominant species was cheatgrass (Bromus tectorum). However, populations of annual plants appeared to be spotty as indicated by the variation in yield among the sampling locations. Average height was 8.3 cm (about 3.25 inches) (Figure 4-57).

B. Sagebrush-Greasewood Vegetation Type

Annual species measured and harvested in this vegetation type were taller and more abundant (Table 4-45) than in the shadscale type (Figure 4-58). Considerable variation in yield was evident from the number of plots in sampling areas 4 and 5 without any annual understory plants. However, annual plants were taller in the sagebrush-greasewood type than in the shadscale type, and biomass production was, on the average, 7 times greater.

C. Juniper Vegetation Type

Height of annual species in this vegetation type averaged 4.2 cm, which was shorter than in either the shadscale or the sagebrush-greasewood types (Table 4-46). Many of the sample plots did not contain any

Table 4-44 Plant height and biomass yield of annual species in the shadscale-sagebrush (Atriplex confertifolia-Artemisia) vegetation type in June 1978. Each value is a mean of data from ten plots.

Sample area 1/	Plant height cm		Biomass yield g/m^2	
1	9.4		5.2	
2	5.8		18.4	
3	8.0	2/	.4	2/
4	10.9		2.0	
5	7.6		1.2	
Average	8.34	Total	27.2	
		Average	5.4	

1/ Areas sampled were within the same locality as in the baseline study.

2/ Only 3 plots in this sampling area had annual vegetation available for sampling.

FIGURE 4-57

Shadscale-sagebrush (Atriplex conterfifolia-Artemisia) vegetation type as it appeared during spring biomass sampling period.

Table 4-45 Plant height and biomass yield of annual species in the sagebrush-greasewood (Artemisia-Sarcobatus) vegetation type in June, 1978. Each value is the mean of data from ten plots.

Sample area 1/	Plant height cm		Biomass yield (g/m^2)
1	19.9		65.2
2	13.5		13.6
3	16.2		88.4
4	11.6 2/		4.4 2/
5	11.2 3/		4.0 3/
Average	14.5	Total	175.6
		Average	35.1

1/ Areas sampled were within the same locality as in the baseline study.

2/ Mean of 5 plots only. Other plots without annual plants.

3/ Mean of 4 plots only. Other plots without annual plants.

FIGURE 4-58

Sagebrush-Greasewood (Artemisia-Sarcobatus vermiculatus) vegetation type as it appeared in spring sampling period

Table 4-46 Plant height and biomass yield of annual species in the Juniper (Juniperus osteosperma) vegetation type in June, 1978. Each number is the mean of data from 10 plots.

Sampling area 1/	Plant height cm		Biomass yield g/m^2
1	4.1		0.4 2/
2	4.4		.8 2/
3	3.2		4.0
4	4.3		2.0 3/
5	5.0		.8 4/
Average	4.2	Total	8.0
		Average	1.6

1/ Areas sampled were the same as in the baseline study.

2/ Only three plots out of 10 contained annual species.

3/ 5 plots out of 10 contained annual species.

4/ 7 plots out of 10 contained annual species.

harvestable biomass and as a result, the average productivity was only 1.6 gm/m^2 (Figure 4-59). In terms of the English weight system this would amount to only 16 pounds per acre. The minimal productivity in the understory of the Juniper trees was consistent with the results obtained in the Baseline study of 1974-75 and 1975-76.

D. Riparian Vegetation Type

This vegetation type (Table 4-47) was more productive than the other three vegetation types in 1978, a pattern which was noted in previous years (Figure 4-60). Plants were from two to seven times taller than in the other vegetation types. Biomass yields were considerably greater than in other vegetation types even though there was some variability among plots.

A few of the randomly-chosen sample plots did not have annual plants growing in them. The average biomass yield of 80 g per square meter (800 pounds per acre) represents a substantial amount of production but is less than the maximum possible under very favorable conditions.

In contrast with the previous year, 1978 was a good year for biomass production. Productivity for Riparian sampling sites 1 and 2, which are located in the White River flood plain, during the past four years yield has varied from 20 g per square meter to over 500 g:

	1975	1976	1977	1978
Average yield in g/m^2	533.25	25.23	20.60	103.0
Standard Deviation			2.47	22.3

FIGURE 4-59

Juniper (Juniperus osteosperma) vegetation type as it appeared in the spring biomass sampling period

Table 4-47 Plant height and biomass yield of annual species in the Riparian vegetation type in June, 1978. Each value is the mean of data from 10 plots.

Sample area [1]	Plant height (cm)	Biomass yield g/m^2
1	25.9	51.2 [3]
2	39.9	154.8 [3]
3	32.6	89.6
4	-- [2]	27.2 [3]
5	19.9	77.2 [3]
Average	29.6	Total 400.0
		Average 80.0

1/ Sampling areas were generally in the same locality as in the baseline study.

2/ Height not recorded for this series of plots.

3/ Three plots in this sampling area did not contain annual species.

FIGURE 4-60

Riparian Vegetation Type

The results of the stem growth monitoring work are summarized in the following discussion. Each of the six sites is discussed individually, followed by some general observations.

Site 1 is in Section 22 about 1/8 mile southwest from exploratory drill sites G-5 and is in the close vicinity of the retort area. This stand of sagebrush appears to have experienced heavy animal use in the previous year. Some seed stems were visible but seed production was not abundant. Surface litter was limited and the stand appeared dry (Figure 4-61).

Site 2 is in the close vicinity of the proposed retort area in the northeast quarter of Section 22. Plants showed evidence of grazing in the previous year. Some plants had abundant (long) regrowth while others were more moderate. The soil was dry and there was limited understory vegetation and current year litter. Only a few plants were noted to be producing seeds (Figure 4-62). No seeds were found on rabbitbrush plants.

Site 3 is near the center of Section 30 along the road to Asphalt Wash and is approximately four miles west of the proposed retort site. This site also showed evidence of grazing in the previous season but there appeared to be good twig growth on many plants (Figure 4-63). Grasses here made good growth but seed production was limited. Small Russian thistle plants were abundant but they had not made their usual late season gain in growth.

Site 4 is in the west center of Section 35 approximately 2 miles south of the proposed retort site. This site appeared very dry. Sagebrush seed stalks were small and did not appear to offer any seed production for 1978 (Figure 4-64). Grazing influence was minor. Understory species were limited and there was only a minimum amount of standing litter.

FIGURE 4-61

Appearance of sagebrush stem sampling location number 1 in Section 22, October 19, 1978.

FIGURE 4-62

Sagebrush sampling site number 2 in northeast quarter of Section 22 in the immediate vicinity of the proposed retort site.

FIGURE 4-63

Sagebrush stem growth measurement site Number 3 along south side of road to Asphalt Wash.

FIGURE 4-64

Sagebrush measurement site Number 4 in Section 35 on south border of oil shale tracts.

Site 5 is in the southeast quarter of Section 19 where the vegetation is primarily shadscale. Sagebrush dominates the north-facing slope of the hill. This site is approximately 3 miles east of the proposed retort location. Halogeton glomeratus was evident in certain exposed areas. Sagebrush was not producing flowers or seeds. Most of the interspace (between shrubs) was bare (Figure 4-65). Rabbits have eaten or cut off many rabbitbrush stems.

Site 6 is on the north side of the White River in Section 4 and is approximately 3.5 miles north of the proposed retort site. Here the sagebrush showed variable growth in comparing individual plants (Figure 4-66). A few flowering stems were producing seeds but many appeared infertile. There was limited understory vegetation. Rabbitbrush plants were not producing seeds. Although this site appeared dry, it was less so than other sites.

Sagebrush stem growth in 1978 appeared to be at least as variable as in previous years. The data show some variability (Table 4-48) for each of the sampling sites. Also, the standard deviation values generally were not proportionately larger than encountered previously.

Average stem length ranged from a low of 5.60 cm as Site 5 east of the tract to a high of 10.07 cm at Site 3 on the road to Asphalt Wash. Sagebrush stem length at the two sites near the proposed retort site had an average twig length of 8.09 to 8.44 cm. Within these sites individual plants had twig lengths ranging from 4 to 12 cm.

On the basis of the average stem length for each site and the respective standard deviation values in 1978, Site 5 showed stem lengths statistically shorter than those in Sites 1 and 2 which were adjacent

FIGURE 4-65

Sagebrush stem length sampling site Number 5.
This site is 3 miles east of proposed retort area.

FIGURE 4-66

Sagebrush stem measuring site Number 6 on
the north side of the White River.

TABLE 4-48

Sagebrush stem length (cm) October, 1978. Data are mean values for 20 stems from individual plants and the standard deviations of such values.

Plant No	Site 1 stem length	SD	Site 2 stem length mean	SD	Site 3 stem length mean	SD	Site 4 stem length	SD	Site 5 stem length	SD	Site 6 stem length	SD
1	7.56	1.65	5.66	2.81	8.86	2.1	4.96	1.1	5.69	1.76	6.07	1.25
2	6.61	3.41	5.08	1.33	9.32	3.54	7.84	1.3	6.52	1.14	7.37	1.78
3	10.85	4.24	5.3	1.31	9.91	2.39	6.02	1.2	4.4	1.07	5.54	1.41
4	7.98	2.85	9.34	1.41	7.54	1.79	5.89	.87	6.21	1.86	6.02	1.29
5	6.98	2.58	6.72	1.19	11.66	2.41	6.77	1.5	4.9	1.1	5.64	1.81
6	8.14	2.68	13.29	2.38	11.24	1.96	4.91	.3	4.88	1.1	5.63	1.51
7	5.61	1.32	9.59	3.89	9.37	2.29	5.11	1.3	5.24	1.7	5.9	1.30
8	12.91	3.56	11.97	1.65	16.82	4.02	6.59	1.1	7.95	1.81	5.74	1.38
9	7.74	2.21	5.76	1.29	9.21	2.65	6.47	1.04	10.5	1.69	6.47	1.79
10	7.97	3.41	5.87	1.39	11.24	2.48	5.55	1.4	4.10	1.06	5.88	1.38
11	9.04	2.02	4.58	1.12	10.13	1.65	6.58	1.3	7.08	1.79	4.85	1.03
12	9.29	1.66	7.18	1.65	10.17	2.26	6.81	1.4	6.53	1.76	9.25	2.57
13	10.04	2.46	6.84	1.91	9.61	1.44	6.11	1.3	5.13	.87	11.14	3.32
14	9.01	2.79	10.99	1.49	12.97	1.76	5.88	1.9	6.54	1.55	7.99	2.23
15	9.39	1.97	5.56	1.72	8.43	1.32	6.29	1.3	4.20	1.62	7.09	1.30
16	10.06	2.34	7.27	2.64	7.28	.67	7.95	1.6	7.59	1.52	6.43	1.47
17	9.09	3.57	14.5	4.57	11.37	1.72	7.13	1.69	7.73	3.1	8.03	3.64
18	7.81	3.29	7.29	1.61	8.06	1.15	7.45	2.1	4.81	1.15	6.68	1.58
19	6.80	1.67	9.79	2.13	8.66	1.90	6.77	1.77	6.16	1.83	6.33	1.64
20	6.08	1.37	9.29	2.18	9.55	2.78	6.63	1.76	5.28	2.01	7.27	1.6
Total	168.88		161.87		201.40		127.71		111.99		129.31	
Average	8.44		8.09		10.07		6.39		5.60		6.47	
SD	1.76		2.88		2.16		1.10		1.59		2.52	

Note: All stem lengths measured in centimeters.

to the proposed retort site. Site 3 was not outside the range of values for Sites 1 and 2 according to the standard deviation ranges calculated.

What use this information would have in terms of evaluating any future impact of retorting activities is not clear at this point. A more comprehensive comparison would be necessary over several years to observe variability in sagebrush growth from site to site. Sampling results in an additional year should help to provide a perspective for this question and at that time an analysis of variance calculation will be performed.

Another source of variation in stem growth is the influence of favorable and unfavorable growing conditions on a yearly basis. Addition of data from 1978 to Table 39 of the 1977 report yields some striking comparisons of yearly effects (Table 4-49). The best year for stem growth would appear to be 1978 which was far superior to the growth measured in 1977. Values for standard deviation were also larger in 1978 than in 1977. Site 3 consistently showed the longest stem length of the six sites over the four year period.

In a general way, stem growth reflected the effects of precipitation, both in amount and pattern. The limited growth response in 1977 was not only the result of a below average amount of precipitation but also a long dry period in the previous winter and early spring. Soil moisture reserves were thus not available to sustain a large amount of stem growth. In 1978 plant growth responses were very favorable in view of the near average amount of precipitation received on the tracts. Periods of precipitation in March and April were apparently beneficial for shrub stem growth.

TABLE 4-49

A comparison of sagebrush stem growth in 1978, 1977, 1976 and 1975 at six sites on oil shale prototype lease tracts Ua and Ub.1/

Site of Measurement		Year of Measurement							
		1975		1976		1977		1978	
Site No.	Description	mean length cm	SD	mean length cm	SD	mean length cm	SD	mean length cm	SD
1.	Industrial site-Sect. 22 G-22	7.39	2.14	6.2	1.04	2.14	.35	8.44	1.76
2.	Industrial site-Sect 22 G-5	6.96	1.12	6.16	1.63	2.03	.25	8.09	2.88
3.	Section 29-3 miles west of industrial site Asphalt Wash	9.69	1.86	7.0	.88	4.04	1.02	10.07	2.16
4.	Section 35-South of Industrial Site	5.60	1.03	5.5	1.06	2.18	.25	6.39	1.10
5.	Section 18-3 miles East of Industrial Site	7.15	1.31	5.4	1.17	2.78	.59	5.60	1.59
6.	Section 3-3 miles No. of Industrial Site	5.37	1.5	4.8	1.08	2.81	.56	6.47	2.52
	Overall Average	7.03		5.9		2.55		7.51	

1/ Each value is the mean length of 20 stems on 20 plants for a total of 400 observations per site.

This background of information will be useful in providing an interpretation of plant response in relation to future oil shale mining and retorting activities. Whether sagebrush stem growth will be useful as an index to the degree fo site favorability remains to be seen. At the present time the amount of plant to plant and within-plant-variability looks to be a problem, but the standard deviation figures indicate a generally close range of values, especially in adverse growing conditions.

As compared with previous years, 1978 demonstrated growing conditions that were nearer the average than the wet year of 1975 or the dry year of 1976. The relatively dry winter was not favorable for germination of annual species which resulted in a spotty stand of such plants. However, if plants did get started, they made moderately good height growth.

The summer months were hot and dry and no doubt resulted in the poor seed set and growth noticed in rabbitbrush and sagebrush. For some reason, fourwing saltbush was not as negatively influenced by the summer drought pattern and produced a good seed set.

Stem growth of sagebrush was better than average for 1978. This growth pattern may well have been a result of the spring precipitation--but certainly not helped by the mid-summer drought.

Grazing use of shrubs (by wildlife and livestock) did not appear to be as intensive as in the previous year. Part of the grazing pressure may have been absorbed by the annual species produced in the late spring.

Suitability of sagebrush stem growth measurements as an environmental favorability index remains to be determined. However, the

measured plant-to-plant variability, site-to-site variability and year-to-year variability is more clearly seen now after four sampling seasons. After the collection of data next year, an analysis of variance comparison will be undertaken. On the basis of standard deviation ranges in relation to means this year (1978) it appears that some populations (sites) are different from those in close proximity to the retort site. However, this is the only year such a difference has been noted.

General observations of site conditions indicate that Baseline vegetation parameters measured in 1975 and 1976 are still valid.

4.3.2 Terrestrial Biology

Terrestrial vertebrates--amphibians, reptiles, birds and mammals--have been monitored for the past four years on the Utah Oil Shale Tracts Ua/Ub (1974-1978). During the Interim Monitoring Program period beginning in December 1976 with completion of the Baseline study and ending in December 1978, three hypotheses concerning the vertebrates have been tested: 1) mammal populations reached a peak in 1976, one year after a desert bloom, declined in 1977, and will stabilize at low abundance or density in 1978; 2) bird populations peaked in 1975 during the desert bloom and were in a downward trend in 1976 and 1977 and will continue to decline in 1978; and 3) reptile populations will remain stable as they have for three years. To test these hypotheses, five criteria established in the two-year Environmental Baseline Monitoring Program have been used:

1) species inventory
2) species distribution within habitat types
3) species distribution within seasons of the year
4) species abundance and density
5) ecological relationships of vertebrates to their biotic and abiotic environment.

Bio-Resources, Inc., performed the work described in the following sections under the direction of Dr. C. V. Grant.

4.3.2.1 Objectives. The primary objective of the program is to extend the data base on terrestrial vertebrates to allow analysis of population trends noted during the Baseline period. A secondary objective is to evaluate control-treatment monitoring techniques which would allow for distinguishing directly between natural cyclic changes and changes attributable to oil shale development activities.

4.3.2.2 Methods. Vertebrate sampling was keyed to the four vegetation communities (Figure 4-67). All vertebrates encountered on and near the tracts were identified to establish a species inventory. Two sampling sites were placed in each plant community to determine spatial distribution, abundance and density. Vertebrates were sampled for two weeks in February, April, June, August and October to determine temporal distribution.

Mammals

Three techniques were used to study the mammals: 1) flushing transects; 2) trapping; and 3) mist netting.

1. Flushing Transects

One flushing transect, one kilometer in length, was established at eight sampling sites. Configuration of each transect was based on topography. Each bend in a transect was marked with a metal fence post, and the transect line was marked with flagging in between posts. Each transect was walked for five consecutive days. Evening transects were walked during a 2.5 hour span, beginning two hours prior to sunset and concluding one-half hour after sunset. Data recorded for each transect were time and date, weather conditions, species observed and heard, including sign (tracks, scats, etc.), number of mammals observed, a mammal's perpendicular distance from the transect line, some behavioral characteristics (feeding, drinking, mating, stationary, moving, etc.), and habitat use (open ground, brush, tree, rock, etc.).

Densities from flushing transect observations were not calculated. Instead, abundance was determined by summing the the mammals observed

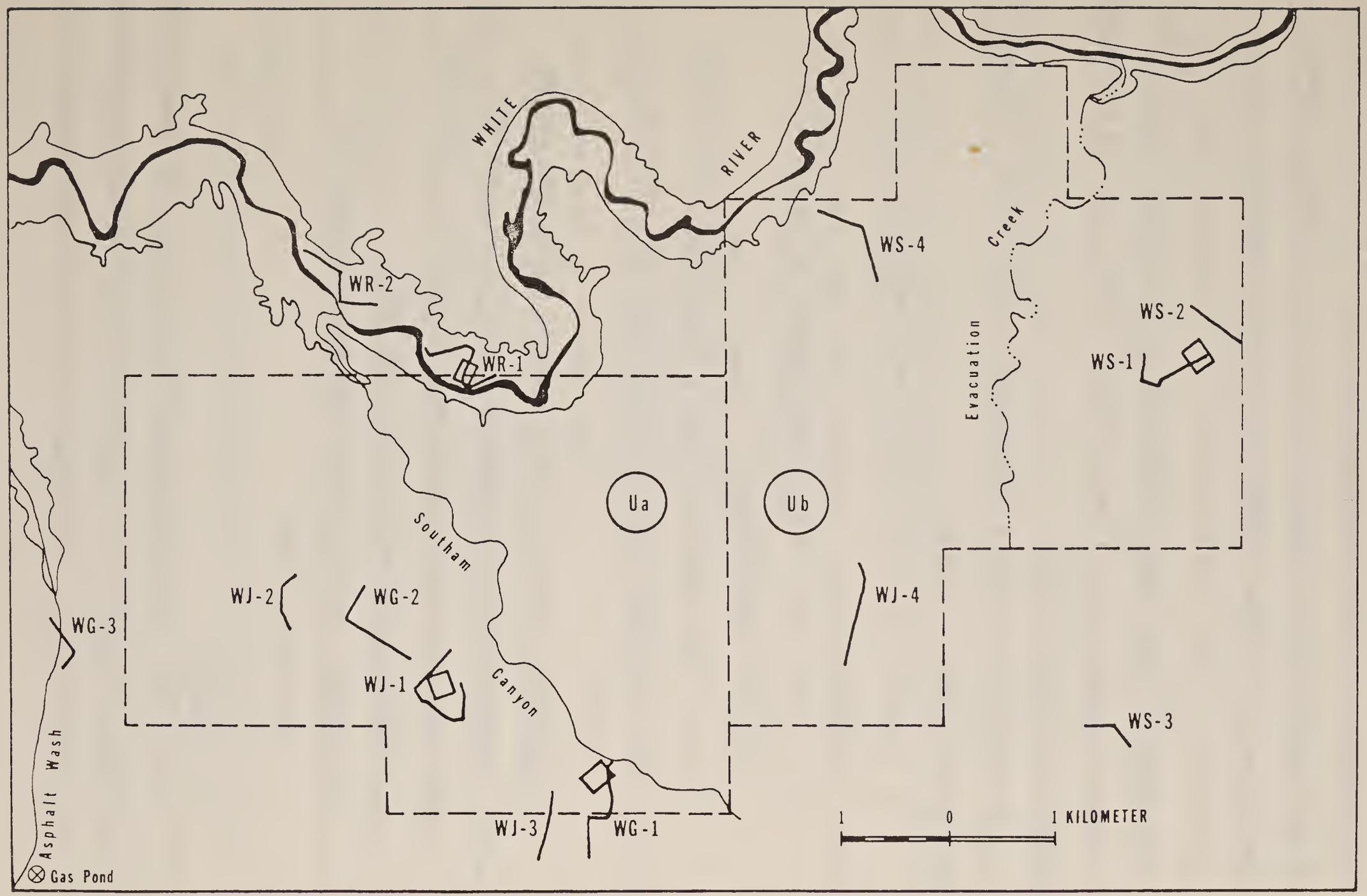


Figure 4-67 Location of flushing transects, large rodent trap grids, and mist-netting site used for terrestrial vertebrate monitoring on the Utah Oil Shale Tracts.

on transect and dividing the sum by the number of kilometers traversed at each sampling site. Abundance was expressed as number/kilometer. Comparisons of mammalian abundance were made by vegetation type, by seasons and by years using the Analysis of Variance and appropriate techniques for ranking means (Steele and Torrie, 1960). Field indentification of mammals has followed Armstrong (1972), Burt and Grossenheider (1976), and Durrant (1952).

Differences in transect methodology for 1977 and 1978 compared to 1975 and 1976 were as follows:

1) Transects WR-1, WR-2 and WG-2 were extended to 1 km in length.
2) Transects WJ-2 and WS-2 were replaced by transects WJ-4 and WS-4, respectively.
3) None of the transects in the 1 mile boundary area around the tract were used in 1977 and 1978, with the exception of WR-2.
4) Distance walked on transects was 40 km/sampling period compared to 37.5 km/sampling period in 1975 and 1976.
5) Sampling periods were two weeks in duration in 1977 and 1978 and three weeks in 1975 and 1976.
6) December samples were not made and an October 1977 sample was not made.

2. Trapping

A 165 x 165 m trap grid was set in each vegetation type during the August sampling period. One hundred forty-four Sherman live traps were set in a 12 x 12 array, 15 m between each trap. Each area (WG-1, WJ-1,

WS-1 and WR-1) (Figure 4-67) was trapped for five consecutive nights. Traps were opened and baited with rolled oats prior to sunset, then checked, emptied and closed the next morning. Size of the traps was 23 x 9 x 7.7 cm.

A captured mammal was identified to species, aged (juvenile or adult), sexed, weighed using 100 g and 500 g capacity Pesola scales, marked individually by toe clipping and released. Capture and recapture locations were recorded, as were physical condition (pregnant, torpor, diseased) and other occurrences (double and triple capture in one trap, number of snapped traps).

Densities were calculated according to the formula D = n/a, where:

D = density (number/hectare)

n = number of mammals captured

a = area covered by trap grid (2.72 ha)

The use of this simple formula was based upon Anderson's (1975) findings in the Curlew Valley of northern Utah.

Movement within a trap grid was calculated for each mammal captured two or more times. The straight line distance (meters) between each trap station was used in lieu of home range estimates (Jennrich and Turner, 1969) due to constraints inherent in the home range formula. A movement value of 7.5 m was used for consecutive rodent captures in the same trap.

Small trap grids were set straddling each transect during the February, April, June and August sampling periods. Twenty-five Sherman live traps were set in a 5 x 5 array, 15 m between traps, covering 0.36 ha. All procedures and calculations were identical to those used in the large trap grids.

Differences in trapping methodology used in 1977 and 1978 compared to 1975 and 1976 were as follows:

1) The riparian trap grid was enlarged to 165 x 165 m, using 144 trap stations. In 1975 and 1976 it was 75 x 165 m, 72 trap stations.
2) Small trap grids were set in a 5 x 5 array each sampling period, compared to a 2 x 12 array in 1975 and 1976.
3) All rodents captured in the small grid during 1977 and 1978 were marked for individual identification, whereas in 1975 and 1976 rodents captured were not individually marked.
4) Trap mortality was reduced by heavily baiting each trap druing February, April and October.
5) All rodents captured were weighed.

3. Mist Netting

The bat sampling program for 1976 was carried out at five separate sites following the suggestions of Greenhall and Paradiso (1968). During May 1976, two sample nights were spent on the banks of the White River at Ignatio Stage Stop and at sampling Site WR-2, and one night at Asphalt Wash gas pond. The mist netting effort during August 1976 was conducted for one night on the sandbars and channels of the White River near sampling Site WR-1, one night at a stock-watering pond north of Bonanza, Utah, and three nights at the gas pond in Asphalt Wash.

Because of consistent capture success the gas pond in Asphalt Wash was the site of all mist netting activities during 1977 and 1978 sampling.

The gas pond was located approximately 0.5 road miles north of the confluence of the west and center forks of Asphalt Wash: T11S, R24E, Sec. 6. The area surrounding the gas pond has extensive greasewood stands. The wash is also a corridor to the White River. The water in the gas pond has a constant replenishment apparently from the Bird's Nest aquifer (Anon., 1977). The gas pond was approximately 50 feet in length, 25 feet in width, with an oval configuration. It was lined with cattails and bullrushes and closely surrounded by a greasewood stand. The pond produced an abundance of flying insects, e.g., Dipterans and Coleopterans.

Two mist nets were set over the pond. The nets were left in position for five nights in June and August, 1977 and 1978, but were rolled up at the end of each night to avoid accidental avian and chiropteran captures. Sampling began each night at 2100 hr. (9:00 p.m.) in June and 2000 hr. (8:00 p.m.) in August, and continued until midnight (2400), sometimes as late as 0300 in 1977. In 1978 nets were up until 0400. No early morning (predawn) sampling was done. The nets were checked on a 15-minute rotation. When multiple captures occurred, the bats were placed in a partitioned box to await measurements and identification. During 1977 and 1978 most bats were identified to species, sexed, weighed, and measured for length of hind foot, high leg, forearm, ear, and body length. Each bat was given a temporary mark to identify recaptures. Handling was kept to a minimum to prevent undue shock to the captured animals. Bats that were wetted were dried as quickly as possible and released. Identification was finalized based on Armstrong (1972) and Barbour and Davis (1969).

Birds

1. Flushing Transects

The same sampling periods, sampling sites, procedures, calculations and comparisons used for mammals were used for birds, with one exception. Bird transects were walked between sunrise and three and one-half hours after sunrise. Birds observed during evening mammal transects were also recorded, as were mammals during morning transects during 1977 and 1978. Field identification of birds has followed Bailey and Niedrach (1965), Peterson (1961), and Robbins, Bruun, and Zim (1966).

Reptiles

1. Flushing Transects

The same sampling sites, procedures, etc. used for mammals were used for reptiles, with two exceptions. Reptiles were sampled in June and August only, and transects were walked beginning three hours after sunrise and concluded three hours after. Reptilian identification has followed Stebbins (1966).

Amphibians

Amphibians were samples on an opportunistic basis. Amphibian identification has followed Stebbins (1966).

4.3.2.3 Data Results.

Mammals

Account of Species

ORDER: CHIROPTERA
Family: Vespertilionidae
Species: 11

The 42 mammals who have visited or resided on the tracts can be divided into two groups--those consistently present from 1975-1978 and

those inconsistently present. The consistent mammals total 20--18 permanent residents, 1 summer resident, and 1 winter resident (Table 4-50). Ten of the mammals are found in all four plant communities. Five are found exclusively in xeric habitats, three in riparian and one or two in xeric habitats, and two in riparian habitat exclusively.

The other 22 mammals are inconsistent residents--3 permanent residents, 11 summer residents and 8 transients (Table 4-51). Two of these mammals are found in riparian habitat exclusively, four in riparian and one or two xeric habitats, and five in xeric habitats exclusively. Eleven mammals, the bats, have been identified in a xeric habitat only, but probably forage and reside in riparian and other xeric communities.

Birds

Account of Species

ORDER: CICONIIFORMES
Family: Ardeidae
Species: 1

A total of 145 avian species have been identified on or near the oil shale tracts from December 1974 through October 1978. The six species observed near the tracts are the whooping crane, Virginia rail, long-billed marsh wren, Bendire's thrasher, lesser goldfinch and the lark bunting.

During the four years of monitoring, 112 different species resided or visited the tracts in 1975 and 116 in 1976. In 1977 and 1978 species number declined to 96 and 95, respectively. Out of the 139 species that have resided or visited the tracts, 77 species are considered consistent in that they have been encountered for four years in succession. Sixty-two species are classified as inconsistent residents and visitors.

Table 4-50 Temporal and spatial distribution of twenty mammalian species which have consistently inhabited the Utah Oil Shale Tracts from December, 1974, to October, 1978.

Habitats
- S-G - Sagebrush-Greasewood
- S - Shadscale
- J - Juniper
- R - Riparian

Habitat Preference
- 1 - Present during 1 year
- 2 - Present during 2 years
- 3 - Present during 3 years
- 4 - Present during 4 years
- 0 - Absent

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
PERMANENT RESIDENTS					Canon Mouse	0	0	4	0
Desert Cottontail	4	4	4	4	Deer Mouse	4	4	4	4
Least Chipmunk	3	3	4	1	Desert Woodrat	4	4	4	1
White-tailed Antelope Squirrel	4	3	4	0	Bushy-tailed Woodrat	3	2	3	4
Golden-mantled Ground Squirrel	4	3	3	4	Muskrat	0	0	0	4
Apache Pocket Mouse	4	4	4	0	Porcupine	1	0	1	4
Ord's Kangaroo Rat	4	4	0	0	Coyote	4	4	4	4
Beaver	1*	1	0	4	Badger	2	2	2	1
Western Harvest Mouse	3	3	2	3	Striped Skunk	0	0	0	4
					Mule Deer	4	4	4	4

Table 4-50 (continued)

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
SUMMER RESIDENT					WINTER RESIDENT				
Domestic Cattle	3	2	0	4	Domestic Sheep	4	4	4	4

*Pond in Asphalt Wash.

Table 4-51 Temporal and spatial distribution of twenty-two mammals which have inconsistently inhabited the Utah Oil Shale Tracts from December, 1974, to October, 1978.

Habitat
- S-G - Sagebrush-Greasewood
- S - Shadscale
- J - Juniper
- R - Riparian

Habitat Preference
- 1 - Present during 1 year
- 2 - Present during 2 years
- 3 - Present during 3 years
- 0 - Absent

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
PERMANENT RESIDENTS					Silver-haired Bat	3*	0	0	0
White-tailed Prairie Dog	1	3	0	1	Western Pipistrel	3*	0	0	0
Brush Mouse	0	1	0	3	Big Brown Bat	2*	0	0	0
Pinon Mouse	1	0	3	1	Western Big-eared Bat	1*	0	0	0
SUMMER RESIDENTS					Hoary Bat	3*	0	0	0
Little Brown Bat	3*	0	0	0	Pallid Bat	3*	0	0	0
Long-eared Bat	3*	0	0	0	TRANSIENTS				
Long-legged Bat	3*	0	0	0	Black-tailed Jackrabbit	0	1	1	0
California Bat	2*	0	0	0	Yellow-bellied Marmot	3	0	0	0
Small-footed Bat	2*	0	0	0	Rock Squirrel	1	0	0	0

Table 4-51 (continued)

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
TRANSIENTS (continued)					Mountain Lion	0	1	0	0
Gray Fox	0	0	0	1	Bobcat	1	1	0	1
Long-tailed Weasel	0	0	1	0	Pronghorn	0	0	0	1

*Pond in Asphalt Wash.

Temporal distribution on a seasonal basis shows that among the consistent birds, 17 are permanent residents, 42 are summer residents, 4 are winter residents and 14 are transients (Table 4-52). Spatial distribution shows that 17 of these birds are found exclusively in the riparian community; 26 species utilize the riparian and one or two of the xeric communities; and 28 species utilize all four communities. Three species, the poor-will, gray flycatcher and plain titmouse, occur exclusively in sagebrush-greasewood and juniper communities. The horned lark, pinon jay and sage thrasher occur exclusively in the three xeric communities.

Among the inconsistent group of birds, 17 are summer residents, 5 are winter residents and 40 are transients (Table 4-53). Spatial distribution shows that 32 species occur exclusively in the riparian community; 20 species occur in the riparian community and one or two xeric areas; 4 species occur in all four habitats; and 6 species occur exclusively in one type of xeric habitat.

Avian abundance reached its highest point in June 1975 averaging 44.8 $\pm$ 22.4 birds/km. The high variability is credited to the 111.7 birds/km found along the White River and Evacuation Creek, whereas 22.5 $\pm$ 2.4 birds/km occurred in the xeric communities. Through four years, June has been the month of peak population, averaging 30.4 birds/km. It is significantly higher than avian abundance in April (14.6/km), October (11.3/km) and February (10.4/km), but not August (16.7/km) (α = 0.05, n = 20, F = 6.26) (Figure 4-68). The riparian community supports a significant abundance at 37.7 birds/km compared to 10.8 km in sagebrush-greasewood, 10.1/km in juniper and 8.5/km in the shadscale community (α = 0.01, n = 16, F = 53.27 (Figure 4-69). February is a

Table 4-52 Temporal and spatial distribution of seventy-seven avian species which have consistently inhabited the Utah Oil Shale Tracts from December, 1974, to October, 1978.

Habitats
- S-G - Sagebrush-Greasewood
- S - Shadscale
- J - Juniper
- R - Riparian

Habitat Preference
- 1 - Present during 1 year
- 2 - Present during 2 years
- 3 - Present during 3 years
- 4 - Present during 4 years
- 0 - Absent

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
PERMANENT RESIDENTS					Black-billed Magpie	4	4	4	4
Cooper's Hawk	2	3	2	4	Common Raven	4	4	4	4
Golden Eagle	4	4	4	4	Piñon Jay	4	4	4	0
Marsh Hawk	3	4	0	3	Black-capped Chickadee	0	0	0	4
Prairie Falcon	4	4	3	3	Plain Titmouse	4	0	4	0
Great Horned Owl	2	2	4	4	Canon Wren	3	0	3	2
Common Flicker	4	2	4	4	Loggerhead Shrike	4	4	3	2
Hairy Woodpecker	0	0	0	4					
Downy Woodpecker	0	0	0	4	SUMMER RESIDENTS				
Horned Lark	3	4	3	0	Great Blue Heron	0	0	0	4
Scrub Jay	2	0	4	2	Canada Goose	0	0	0	4
					Turkey Vulture	2	4	2	4

Table 4-52 (continued)

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
SUMMER RESIDENTS (continued)					Rough-winged Swallow	2	2	1	4
Red-tailed Hawk	4	4	4	4	Cliff Swallow	2	3	1	4
American Kestrel	4	4	4	4	Rock Wren	4	4	4	4
Killdeer	0	2	0	4	Sage Thrasher	3	4	2	0
Spotted Sandpiper	0	0	0	4	American Robin	2	2	3	4
Mourning Dove	4	4	4	4	Mountain Bluebird	4	4	4	4
Poor-will	1	0	4	0	Blue-gray Gnatcatcher	3	0	4	4
Common Nighthawk	4	4	4	4	Starling	0	3	0	4
White-throated Swift	3	3	3	4	Warbling Vireo	0	0	0	4
Broad-tailed Hummingbird	2	1	1	4	Yellow Warbler	1	1	0	4
Ash-throated Flycatcher	3	0	2	4	Black-throated Gray Warbler	4	0	4	4
Say's Phoebe	4	4	4	4	Yellow-breasted Chat	0	0	0	4
Willow Flycatcher	0	0	0	4	Western Meadowlark	4	4	2	4
Gray Flycatcher	4	0	4	0	Northern Oriole	0	0	0	4
Western Wood Peewee	1	0	2	4	Brown-headed Cowbird	1	2	2	4
Violet-green Swallow	3	2	1	4	Blue Grosbeak	0	0	0	4

Table 4-52 (continued)

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
SUMMER RESIDENTS (continued)					Barn Swallow	0	2	1	3
House Finch	3	3	4	4	Ruby-crowned Kinglet	1	0	2	4
American Goldfinch	0	0	1	4	Cedar Waxwing	0	0	0	4
Rufous-sided Towhee	3	0	2	4	Yellow-rumped Warbler	3	0	2	4
Lark Sparrow	4	4	3	4	Red-winged Blackbird	1	0	0	4
Black-throated Sparrow	4	4	4	2	Brewer's Blackbird	2	3	2	4
Sage Sparrow	4	4	1	2	Vesper Sparrow	1	4	0	1
Chipping Sparrow	4	0	3	3	Gray-headed Junco	1	0	2	3
Brewer's Sparrow	4	4	0	3	White-crowned Sparrow	3	2	0	4
TRANSIENTS					WINTER RESIDENTS				
Mallard	0	0	0	4	Goshawk	0	0	2	4
Green-winged Teal	0	0	0	4	Bald Eagle	0	2	0	4
Common Merganser	0	0	0	4	Black Rosy Finch	3	2	3	3
Sandhill Crane	0	0	0	1	Dark-eyed Junco	3	0	4	4
Belted Kingfisher	0	0	0	4					

Table 4-53 Temporal and spatial distribution of sixty avian species which have irregularly inhabited the Utah Oil Shale Tracts from December, 1974, to October, 1978.

Habitats
- S-G - Sagebrush-Greasewood
- S - Shadscale
- J - Juniper
- R - Riparian

Habitat Preference
- 1 - Present during 1 year
- 2 - Present during 2 years
- 3 - Present during 3 years
- 0 - Absent

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
SUMMER RESIDENTS					MacGillivray's Warbler	1	0	0	2
Yellow-billed Cuckoo	0	0	0	1	Common Yellowthroat	0	0	0	3
Eastern Kingbird	1	0	0	2	Wilson's Warbler	1	0	0	2
Western Kingbird	1	2	1	2	Western Tanager	0	0	0	3
House Wren	1	0	0	3	Black-headed Grosbeak	0	0	0	2
Bewick's Wren	2	0	3	1	Lazuli Bunting	1	0	1	3
Mockingbird	1	0	0	0	Song Sparrow	0	0	0	3
Black-tailed Gnatcatcher	1	0	1	1					
Solitary Vireo	0	0	0	3	TRANSIENTS				
Orange-crowned Warbler	0	0	0	3	Gadwall	0	0	0	2
Virginia's Warbler	1	0	0	1	Pintail	0	0	0	1
					Blue-winged Teal	0	0	0	2

Table 4-53 (continued)

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
TRANSIENTS (Continued)					Yellow-bellied Sapsucker	0	0	0	2
Cinnamon Teal	0	0	0	2	Eastern Phoebe	1	0	0	1
American Wigeon	0	0	0	1	Western Flycatcher	0	0	0	1
Northern Shoveler	0	0	0	2	Olive-sided Flycatcher	0	0	0	1
Sharp-shinned Hawk	1	1	1	2	Tree Swallow	1	0	0	1
Swainson's Hawk	0	1	0	0	Common Crow	0	0	0	1
Peregrine Falcon	1	0	0	1	Clark's Nutcracker	0	0	1	0
Merlin	0	0	0	1	Mountain Chickadee	0	0	1	1
Chukar	0	1	0	0	White-breasted Nuthatch	0	0	0	3
Ring-necked Pheasant	0	1	0	1	Red-breasted Nuthatch	0	0	1	1
Common Snipe	0	0	0	1	Brown Creeper	0	0	0	1
Greater Yellowlegs	0	0	0	2	Hermit Thrush	0	0	0	2
American Avocet	0	0	0	1	Swainson's Thrush	0	0	0	2
Short-eared Owl	0	1	0	1	Western Bluebird	0	0	1	2
Black-chinned Hummingbird	0	0	0	1	Townsend's Solitaire	1	0	2	3

Table 4-53 (continued)

Species	Habitat			
	S-G	S	J	R
TRANSIENTS (Continued)				
Water Pipit	0	0	0	2
Red-eyed Vireo	0	0	0	1
Townsend's Warbler	0	0	0	1
Scott's Oriole	3	0	2	1
Rose-breasted Grosbeak	0	0	1	0
Pine Siskin	0	0	0	1
Green-tailed Towhee	1	0	0	2
Savannah Sparrow	0	1	0	0
WINTER RESIDENTS				
Rough-legged Hawk	1	1	1	2
Long-eared Owl	0	0	0	2
Bushtit	2	0	3	2
Gray-crowned Rosy Finch	1	1	1	2
Tree Sparrow	0	0	0	2

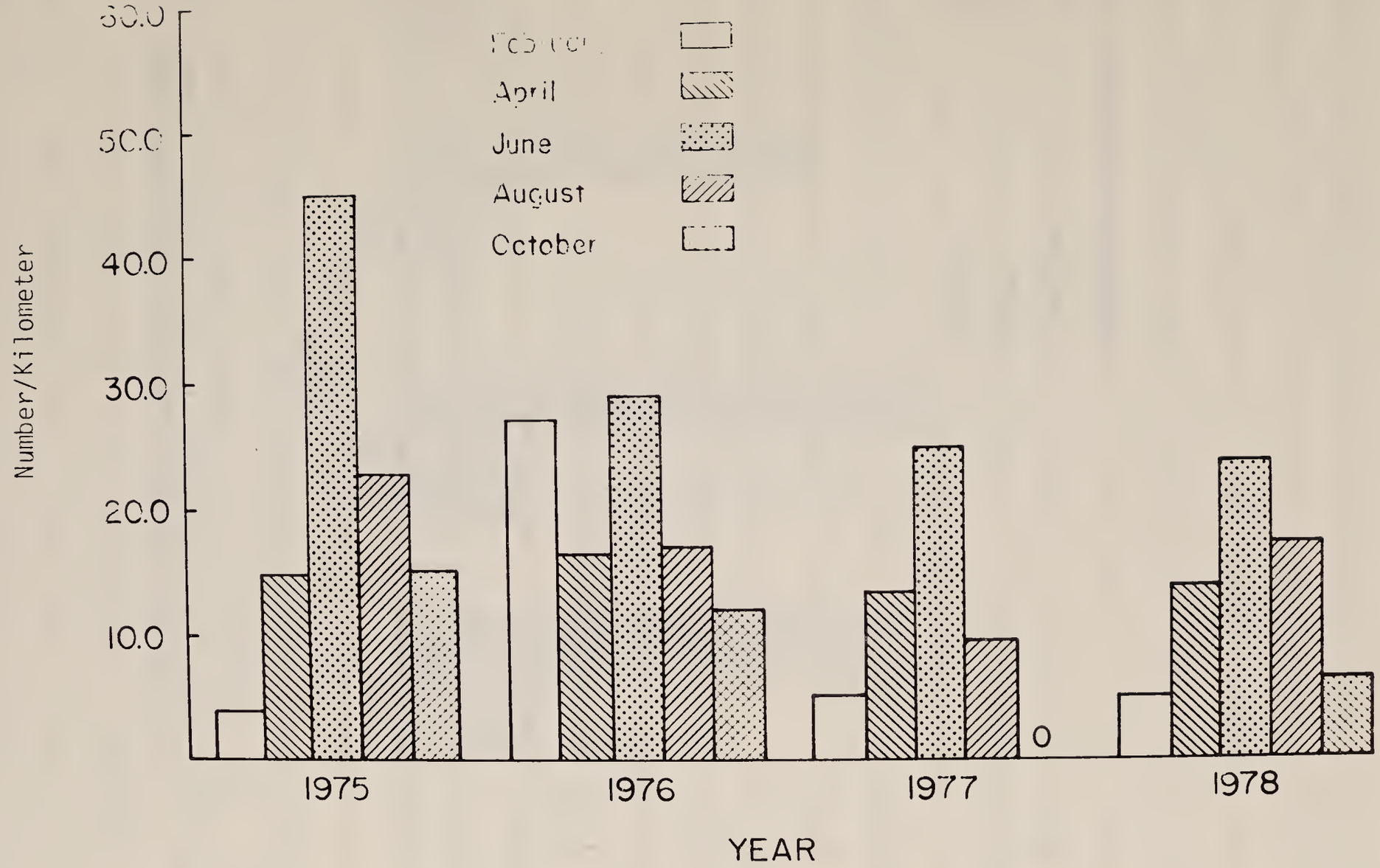


Figure 4-68 Avian abundance during the winter (February), spring (April and June), summer (August), and fall (October) on the Utah Oil Shale Tracts in the Uintah Basin.

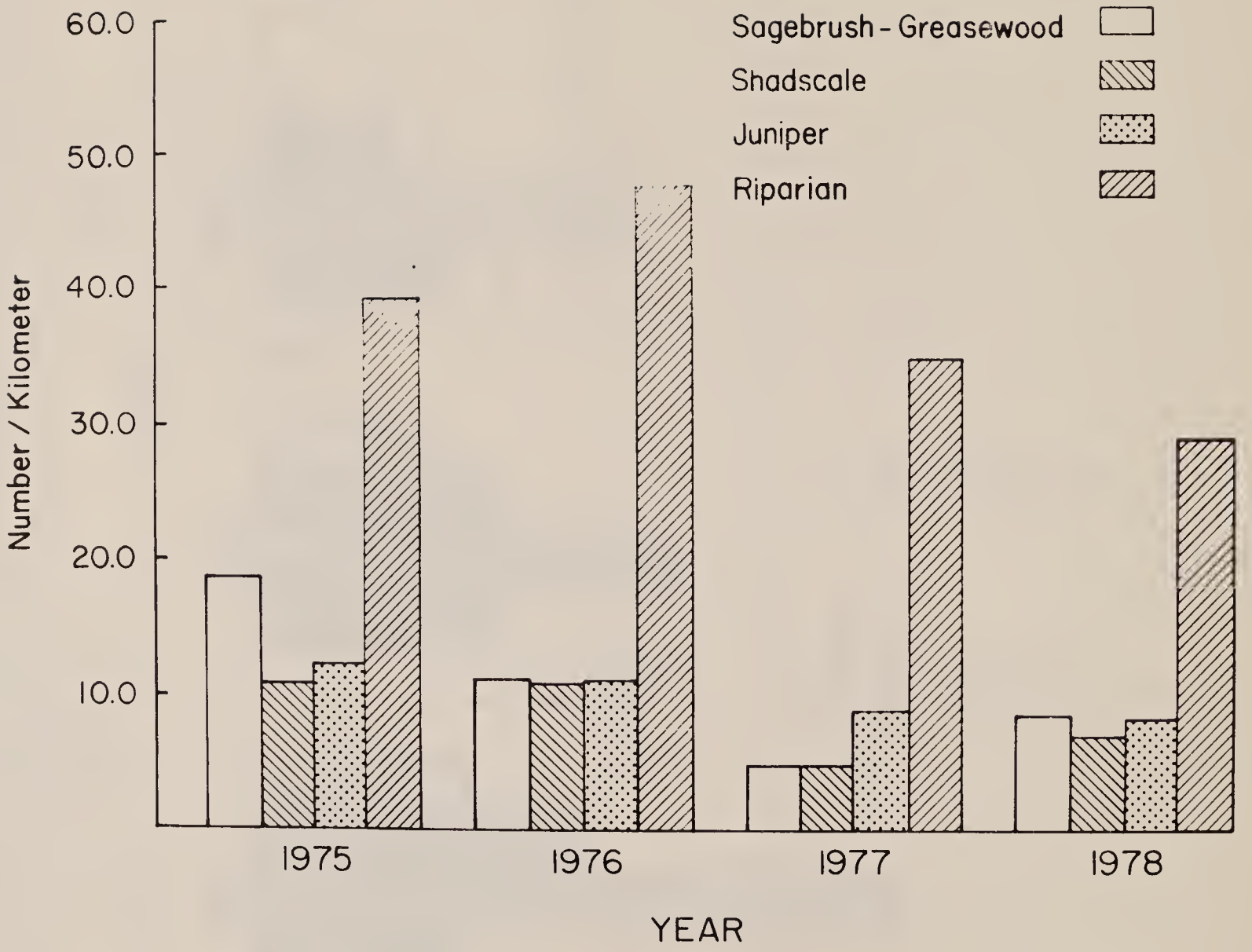


Figure 4-69 Annual avian abundance in four vegetation communities on the Utah Oil Shale Tracts in the Uintah Basin.

time of the year that abundance in one or two of the xeric communities will exceed abundance in the riparian community. The latter area can be the most inhospitable on the tracts during winter due to cold air drainage, humidity, and in some areas almost constant shading due to the earth's declination and high canyon walls. Abundance in xeric habitats has exceeded riparian abundance two other times--in the sagebrush-greasewood in August 1975 and in the juniper in October 1978.

On an annual basis, avian abundance during 1975 and 1976 was virtually equal, averaging 20.4 birds/km and 20.3 birds/km, respectively. During 1977 and 1978 avian abundance declined significantly to 13.2 birds/km, respectively (α = 0.05, n = 16, F = 4.59). The reason annual abundance remained high in 1976 was the influx of large flocks of winter residents, specifically the rosy finches and dark-eyed juncoes. Their presence during February in the riparian community resulted in an abundance of 77.1 birds/km which exceeds June abundance in the riparian community from 1976-1978. This high winter abundance appears to be due to two factors--the desert bloom of 1975 which led to high seed production and the mild winter in 1976 which marked the beginning of a two-year drought.

Some of the changes that have taken place on the tracts are illustrated by the change in populations of three groups of birds. First are the granivores, the seed-eaters in the family Fringillidae. They reached their peak abundance in June and August 1975. Since that time their populations have been in steady decline (Figure 4-70).

The second group is the flying insectivores, nighthawks, swifts and swallows. Their abundance peaked in June 1975; by August their decline was one of the most drastic changes seen on the tracts. During 1976

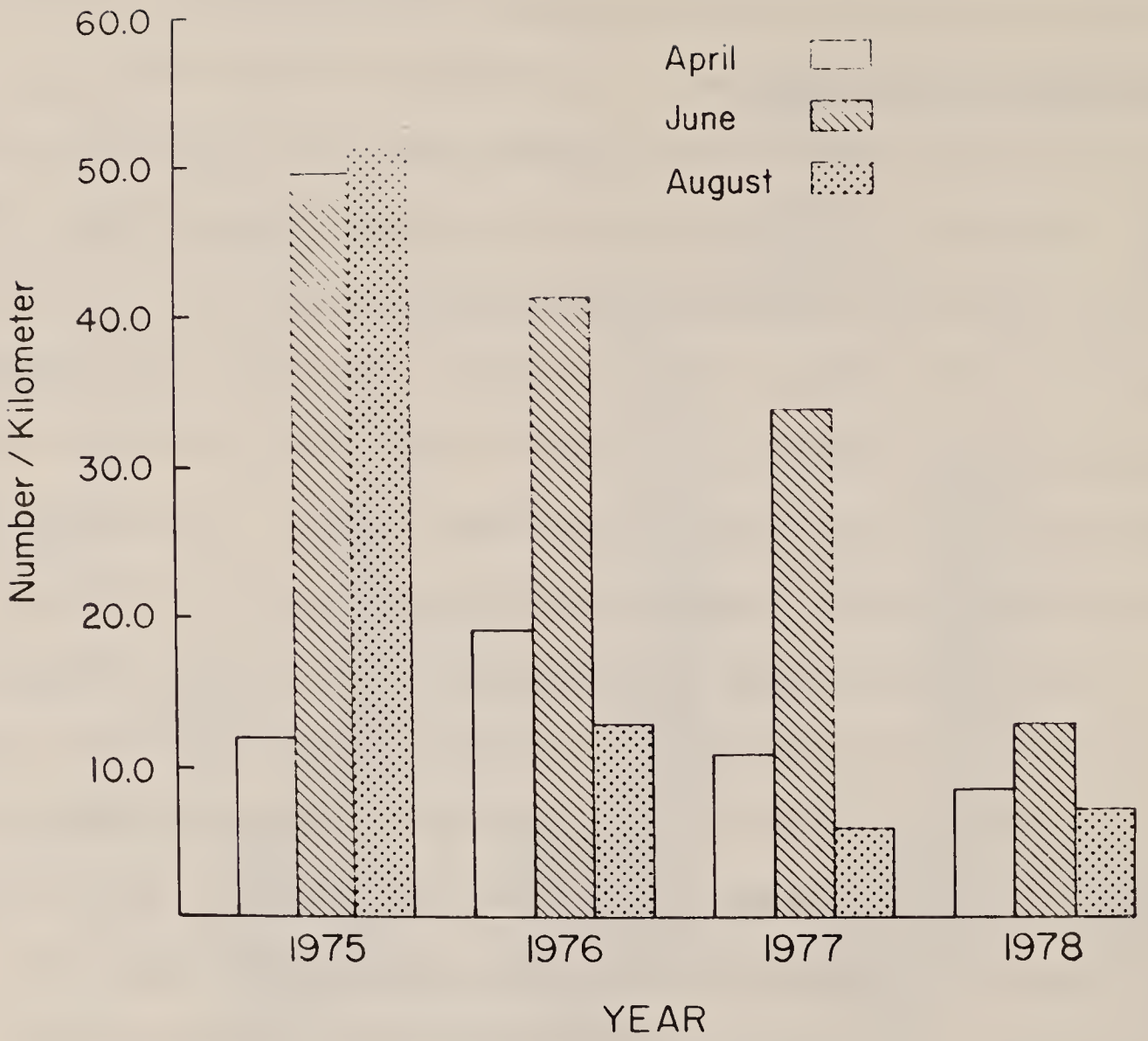


Figure 4-70 Abundance of granivorous birds of the family Fringillidae during spring and summer on the Utah Oil Shale Tracts in the Uintah Basin.

and 1977 their abundance did not exceed 6 birds/km. In 1978 when spring precipitation matched that of 1975, June abundance rose again. By August, instead of drastically declining, abundance remained relatively high (Figure 4-71). The difference in weather patterns between 1975 and 1978 was that in the latter year the summer was hot, dry and windy, whereas 1975 tended to be cool and wet. Population change in these brids from 1976-1978 follows the same pattern as changes in bat populations.

The third group, rather than demonstrating a rise or fall in population, presents a stable abundance through four years. The tree and brush insectivores--flycatchers, gnatcatchers, vireos, warblers and orioles--have maintained a relatively stable abundance when viewed as a group, rather than by species (Figure 4-72). Although some of these birds, such as Say's phoebes and gray flycatchers, are more dependent on the dryland communities, the bulk of the tree and brush insectivores' populations is found along the White River.

Overall, the birds appear to reflect the immediate state of the environment. When conditions are good, the birds stay and exploit the area. When conditions are adverse, they appear to use the area for short periods, then move elsewhere, apparently following their food supply.

Reptiles

Account of Species

ORDER: SQUAMATA
Family: Iguanidae
Species: 5

The eleven reptiles shown on Table 4-54 are the most consistent of the terrestrial vertebrates on the tracts. All are permanent residents, active from April through October. Most are found in the four plant

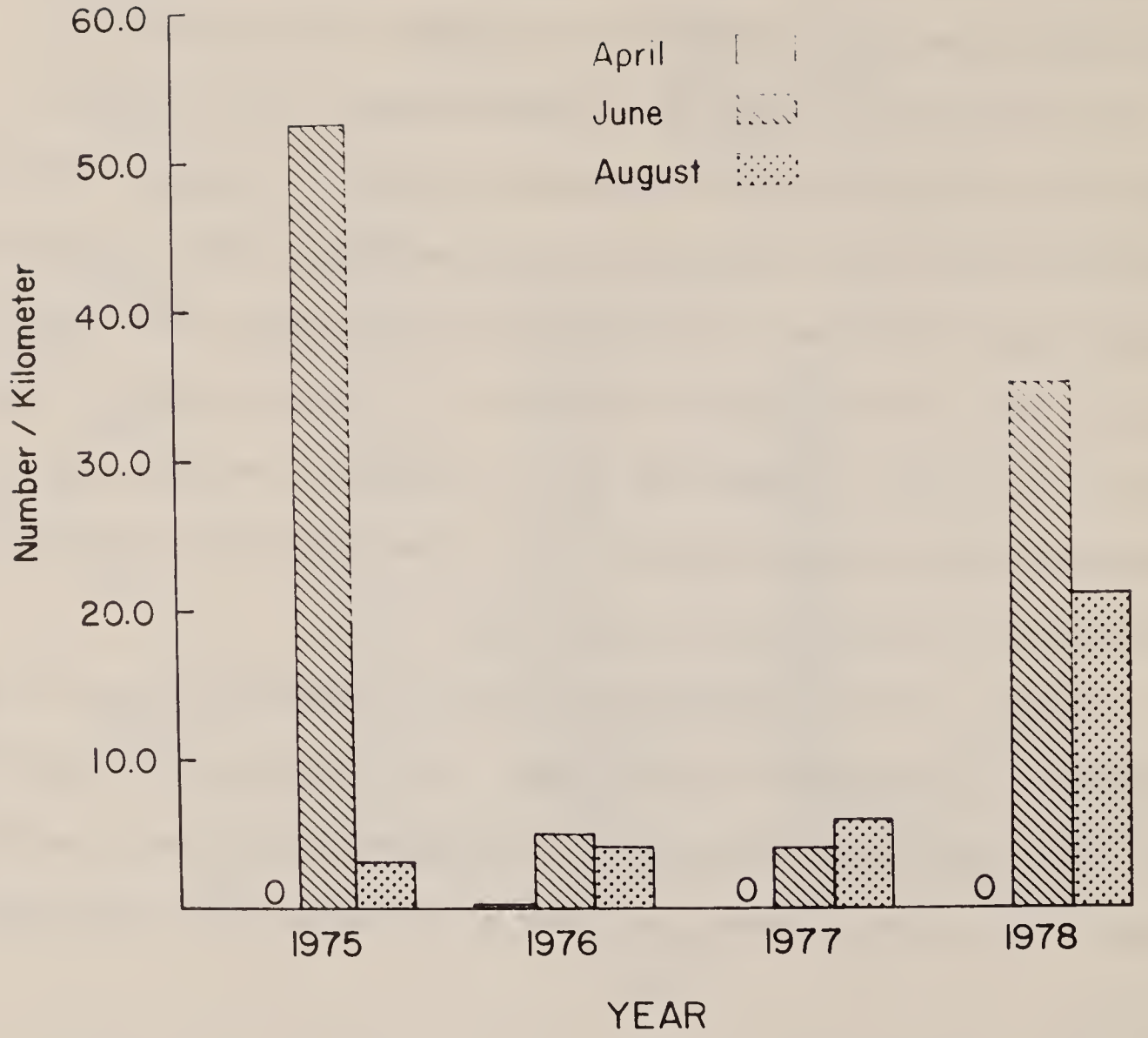


Figure 4-71 Abundance of insectivorous birds (nighthawks, swifts, and swallows) during spring and summer on the Utah Oil Shale Tracts in the Uintah Basin.

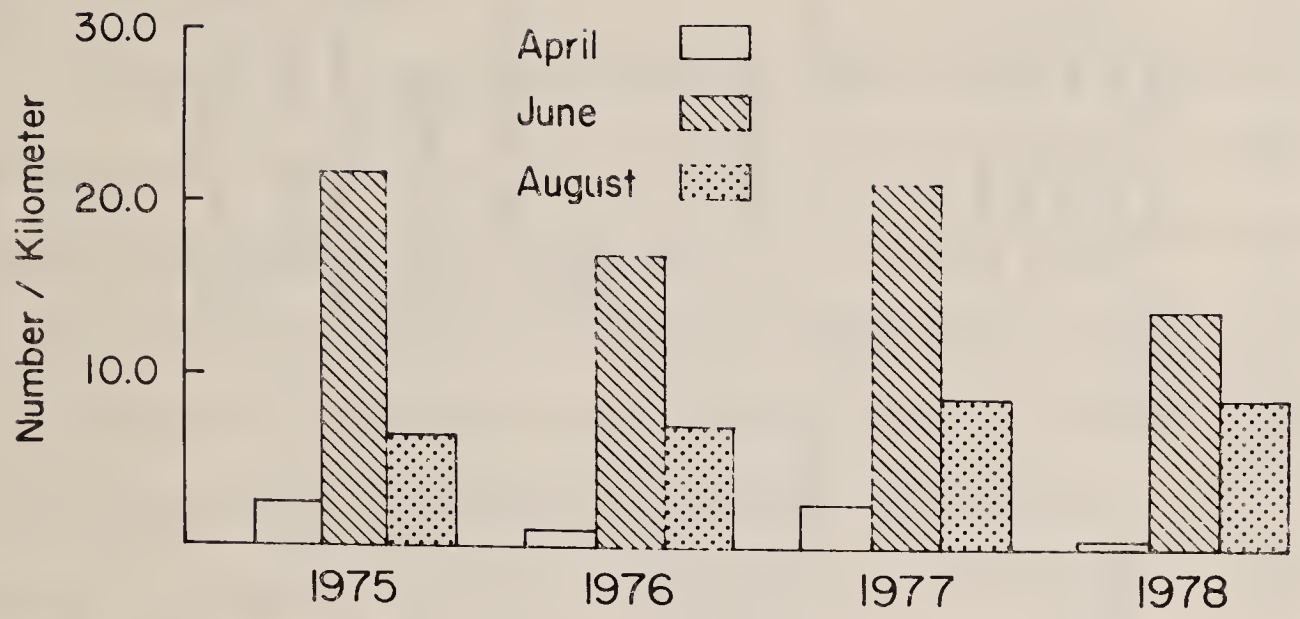


Figure 4-72 Abundance of tree and brush insectivorous birds (flycatchers, gnatcatchers, vireos, warblers, and orioles) during spring and summer on the Utah Oil Shale Tracts in the Uintah Basin.

Table 4-54 Temporal and spatial distribution of eleven reptiles which have consistently inhabited the Utah Oil Shale Tracts from April through October, 1975-1978.

Habitat
- S-G - Sagebrush-Greasewood
- S - Shadscale
- J - Juniper
- R - Riparian

Habitat Preference
- 1 - Present during 1 year
- 2 - Present during 2 years
- 3 - Present during 3 years
- 4 - Present during 4 years
- 0 - Absent

Species	Habitat				Species	Habitat			
	S-G	S	J	R		S-G	S	J	R
PERMANENT RESIDENTS					Racer	0	0	0	4
Eastern Fence Lizard	3	4	4	4	Striped Whipsnake	4	4	1	2
Sagebrush Lizard	4	4	4	4	Gopher Snake	4	4	3	4
Side-blotched Lizard	4	4	4	4	Western Terrestrial Garter Snake	0	0	0	3
Tree Lizard	2	2	4	4	Western Rattlesnake	4	3	2	1*
Short-horned Lizard	2	4	0	0					
Western Whiptail	4	4	4	4					

*Evacuation Creek only.

communities, except for three. The only reptile that has not been found consistently is the western terrestrial garter snake, none being encountered in 1978.

Snake abundance is quite low, based on the number of encounters per time in the field. Abundance reached its peak in late summer of 1976, coincident with peak rodent density. Since that time, snakes have been encountered infrequently. Considering the number of lizards in the area, snakes are rare reptiles.

Abundance of lizards--expressed as number/km--is somewhat misleading and should be viewed with the following points in mind. Lizards are primarily ground dwellers; they are small and when walking, transects are usually observed within 0-1 m of the transect line. Seldom do observations exceed 5 m beyond the line. Observations of birds and mammals, on the other hand, can exceed 100 m beyond the transect line. Thus, the lizards are considered the most abundant vertebrates on the tracts. They are also the most seasonal, appearing sporadically in April and October and at peak activity in June and August.

Where mammals and birds have shown population fluxes, lizards have sustained a stable population (Figure 4-73). Through a desert bloom, two years of drought and a fourth year of what may be the norm, overall lizard abundance has changed little in response to environmental fluctuations which have significantly affected birds and mammals.

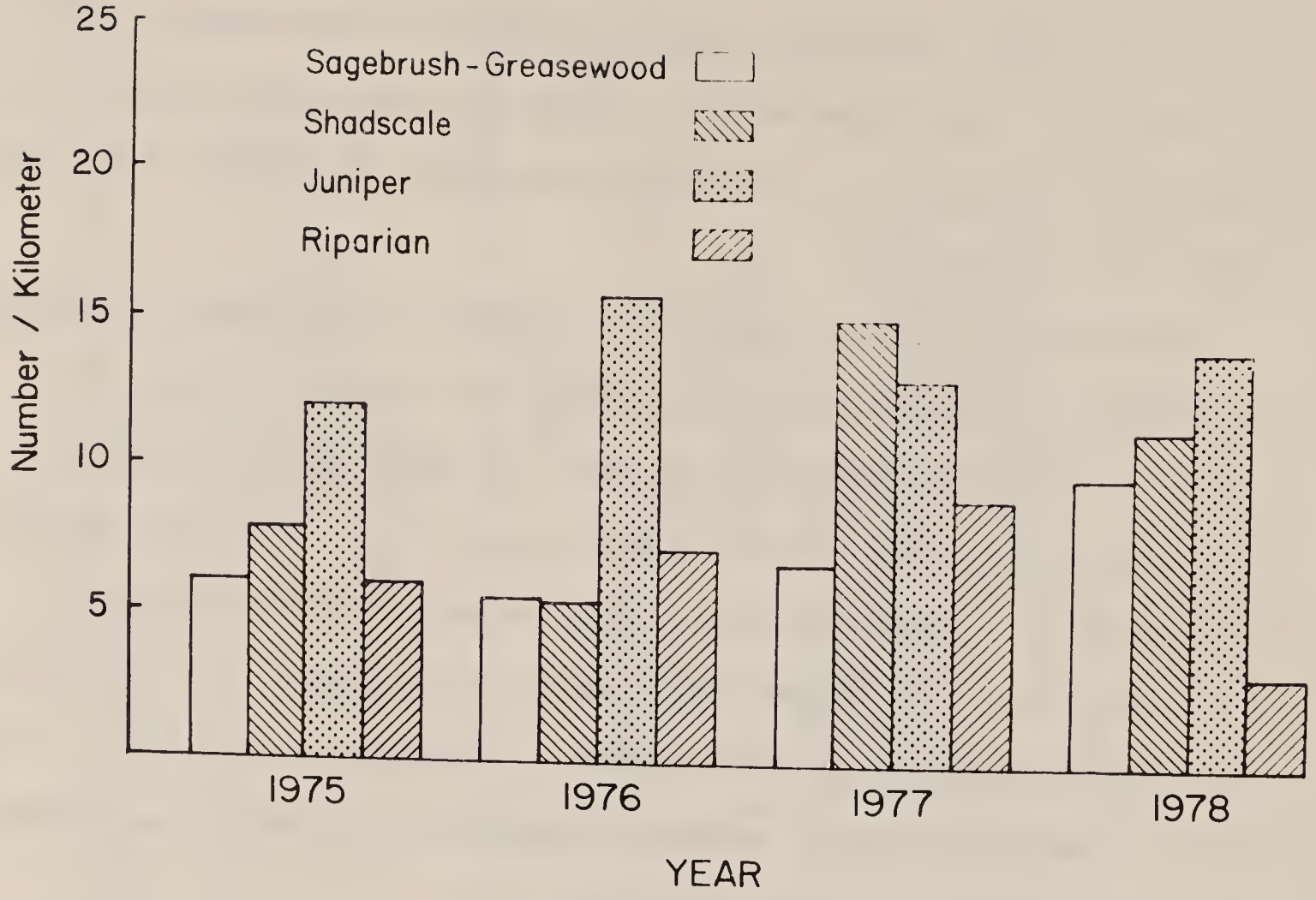


Figure 4-73 Abundance of lizards in four vegetation communities on the Utah Oil Shale Tracts in the Uintah Basin

Amphibians

Account of Species

ORDER: SALIENTIA
Family: Pelobatidae
Species: 1

Little is known of the amphibian abundance. The only indication of abundance has been the vocalization of amphibians which peaked in June 1976. The ability of the toads to traverse dry lands has extended their distribution to stockponds throughout the area. Notably no toads or frogs have been found along Evacuation Creek.

4.3.2.4 Control-Treatment Sites

When some sampling sites were relocated and some transects extended from 0.5/km to 1.0/km in length in 1977, the plan was to use one sampling site in one vegetation type as a control point and one sampling site in the same vegetation type as a treatment point. The plan assumed that birds, mammals and reptiles would respond synchronously on both sampling sites within each vegetation type. The sampling site located away from mining operations would eventually serve as a control for immediate changes outside the affected area and provide direction for rehabilitating the treated area.

Due to variation within each vegetation type, the control-treatment plan did not work as planned, at least not from a simple quantitative view. The paired sampling sites proved worthwhile in reducing variation of vegetation types. More sophisticated statistical treatment will be needed to determine how the control and treatment areas were similar or different and to what degree. With the third year of information available in 1979, more refined analyses will be applied to control-

treatment sites to determine whether the control-treatment designation is usable. The view from the last two years suggests asynchronous variation.

4.3.2.5 Discussion

Identification, distribution, and population abundance and density of 202 land animals on the Utah oil shale tracts provides a collage of structure and function among and within four classes of terrestrial vertebrates. Although many pages could be filled discussing the data and its application to biological theory, the primary concern is to establish a sound baseline by which effects of mining development, operation, and rehabilitation either impact or enhance the vertebrates on the tracts. The majority of discussion will refer to this goal; however, rather than allow theory to stand unassailed, the area of population biology deserves a few comments.

Much discussion about animal populations have been generated by Lack (1954, 1966) and Wynne-Edwards (1962). It is Bio-Resource's conclusion that Wynne-Edwards more closely touches reality by stressing social behavior within a species as the main impetus for population change rather than Lack's food resources. However, both gentlemen stress the energy quadrant of environment and disregard three other areas. One of these areas--weather and its effects on population dynamics--has been emphasized by Andrewartha and Birch (1954). Two other areas which have lacked emphasis in population biology are: 1) geology and soils, and 2) water relationships. When these four variables--energy, weather, geology and hydrology--are considered

both separately and as a whole, theoretical determinants of population dynamics have to be reconsidered.

Returning to the animals on the tracts, each species plays a role indicative of the tract's environment. Deer mice and desert cottontails reflect changing conditions tract-wide and in separate habitats, whereas pocket mice and kangaroo rats reflect a stability within two xeric habitats. The presence of Bendire's thrasher and western bluebirds may suggest range expansion. The measurable abundance of Virginia's warblers and black-tailed gnatcatchers suggests that 1975 provided distinctly different conditions in the Uintah Basin. Sage sparrows have demonstrated a preference for the shadscale community when conditions and their populations declined, as have loggerhead shrikes and western meadowlarks. Black-throated sparrows have gravitated to the sagebrush-greasewood community under the same pressures. Brewer's sparrows and chipping sparrows simply stopped residing in number on the tracts. All in all, there are 202 indicators that have resided or visited this 41.4 square kilometer area in the Uintah Basin.

Considering the animals by their class--Mammalia, Aves, and Reptilia--each class reflects three different views of environmental conditions. The migratory birds have the ability to move into an area, test its suitability, and either remain to nest and raise their young or, if conditions are adverse, move on to another location. Their pattern of movement appears to be keyed to an immediate situation. When the tracts bloomed in the spring of 1975, birds reached their highest abundance and species diversity. In the first year of drought in 1976 diversity remained high but spring abundance declined.

Abundance continued to decline as did diversity in the second year of drought in 1977. By 1978, abundance and diversity stabilized in what may be the base population levels for migratory birds on the tracts. The point is that these birds appear to respond to the immediacy of environmental change; thus, their presence, absence, and abundance are the first indicators of the direction of natural change or stability.

Since the birds have the prerogative to leave or stay, their presence and abundance is more of a surficial indicator. One can measure that a change has taken place through the birds, but the birds do not indicate the extent or magnitude of change. They are analogous to a surficial geology survey, which shows what is immediately present. Until the depth of a formation and its relationship to other unseen layers is determined, surface layers are merely suggestive. The deeper layers in the vertebrate kingdom come from mammals and reptiles.

Determining the response of mammal populations to environmental changes, specifically the rabbits and rodents, does not become clear until a year after the birds have provided their input. Since most of these mammals are permanent residents, a rapid change in resources is of little benefit. Rabbits and rodents must rely on long-term benefits which can sustain them through the winter and augment reproductive success during the next year. Following the desert bloom in 1975, rabbit populations were low and rodent populations seemed to be increasing. The magnitude of increase was not experienced until 1976 when some of these mammals quadrupled in number, this occurring during a drought. The magnitude of the drought was not evident until 1977 when populations of rodents declined precipitously, whereas rabbits

maintained a moderate and stable abundance. The effects of continued drought in 1977 were expressed by a decline in rabbits in 1978 and a slight resurgence in rodent numbers.

Birds have been the harbingers of change; mammals have been the yardstick for the depth and magnitude of what bird populations indicated. We come to the reptiles who apparently represent the deepest layer in the terrestrial vertebrate kingdom--deepest in the sense that what has significantly affected birds and mammals has yet to affect the reptiles, specifically the lizards. Some lizard species have declined; others have increased. Yet, overall, their presence and abundance has remained unchanged. Although they are permanent residents, their seasonal activity protects them from harsh elements which affect both birds and mammals. It may well be that the lizards are the most reliable indicators of man-induced change in the sense that they form the bedrock of the vertebrates. If and when their populations increase or decline, the stimulus for this change will probably be readily evident.

In reference to man-induced change, the most reliable indicators of impact or enhancement will be the permenent and consistent residents of the three vertebrate classes mentioned. Whether man's actions can affect the decimation or proliferation of any one vertebrate is amply demonstrated by species such as the buffalo and the starling. It appears that less severe or extensive effects can be identified by population dynamics of classes of vertebrates concerning natural versus man-induced impact or enhancement. Augmenting these general indicators, species can indicate impact or enhancement by habitat and season.

LITERATURE CITED

Anderson, R. D. 1975. Vertebrates. In Curlew Valley Validation Site Report, J. A. MacMahon, Coordinator, Utah State Univ., Logan. US/IBP Desert Biome Res. Memo. 75-1:48-60.

Andrewartha, H. G. and L. C. Birch. 1954. The Distribution and Abundance of Animals. Univ. Chicago Press: Chicago and London. 782 pp.

Armstrong, D. M. 1972. Distribution of Mammals in Colorado, Univ. Kansas, Mus. Nat. Hist., Monogr. 3:1-415.

Bailey, A. M. and A. J. Niedrach. 1965. Birds of Colorado. Denver Mus. Nat. Hist. Vol. 1:1-454; Vol. 2:455-895.

Barbour, R. W. and W. H. Davis. 1969. Bats of America. Univ. Kent. Press: Lexington. 286 pp.

Burt, W. H. and R. P. Grossenheider. 1976. A Field Guide to the Mammals. Houghton Mifflin Co.: Boxton. 289 pp.

Durrant, S. D. 1952. Mammals of Utah. Univ. Kansas Publ., Mus. Nat. Hist. 6:1-549.

Greenhall, A. M. and J. L. Paradiso. 1968. Bats and Bat Banding. Fish and Wildl. Serv., BSFW Res. Publ. 72:1-47.

Jennrich, R. L. and F. B. Turner. 1969. Measurement of noncircular home range. J. Theoret. Biol. 22:227-237.

Lack, D. 1954. The Natural Regulation of Animal Numbers. Claredon Press: Oxford. 343 pp.

Lack, D. 1966. Population Studies of Birds. Claredon Press: Oxford. 341 pp.

Peterson, R. T. 1961. A Field Guide to Western Birds. Houghton Mifflin Co.: Boston. 309 pp.

Robbins, C. S., B. Bruun, and H. S. Zim. 1966. Birds of North America. Golden Press: New York. 340 pp.

Stebbins, R. C. 1966. A Field Guide to Western Reptiles and Amphibians. Houghton Mifflin Co.: Boston. 279 pp.

Steele, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co.: New York. 481 pp.

Wynne-Edwards, V. C. 1962. Animal Dispersion in Relation to Social Behavior. Oliver and Boyd: Edinburgh and London. 653 pp.

Section 5.0

REVEGETATION RESEARCH PROGRAM

In 1974 the Range Science Department of Utah State University was placed under contract to investigate revegetation techniques for processed shale as well as rehabilitation of disturbed sites.

5.1 Objectives

The objective of this research is to develop a technology for revegetating disturbed sites and processed shale disposal areas.

5.2 Results to Date

The final report entitled "Revegetation Studies for Disturbed Sites and processed Shale Disposal Sites" was completed covering the period November 1, 1974 to December 31, 1978. This section summarizes findings presented in the final report.

5.2.1 Highlights of the Final Report

The approach followed in the present research was to utilize natural means and materials where possible and to minimize the requirements for scarce resources such as water. Thus, the general rehabilitation recommendations are alternatives to some of the practices and recommendations previously reported by groups working in oil shale land rehabilitation.

Two main problems were addressed in the research program: revegetation of disturbed sites and rehabilitation of processed oil shale disposal piles. To provide data necessary for a technology to solve these two problems over 40 field and laboratory studies were conducted. We have

studied various aspects of these two problems as far as we could under the variable site conditions and limited quantities of processed oil shale available for research.

Successful revegetation of disturbed sites under the environmental conditions of limited and erratic precipitation, great temperature extremes from winter cold to summer heat, and shallow soil of low fertility and often high salinity requires considerably more than direct seeding of adapted species. Transplanting of bare root or container-grown transplants of native or naturalized species can assure success in plant establishement under stress conditions. Competition control will enhance plant survival. Wildlife and grazing control also can improve success in plant persistence.

The Rehabilitation Plan

A system for rehabilitation of processed oil shale was proposed at the outset of the research program. The proposed system consists of seven compatible components that can function in a logical and co-ordinated fashion:

1. Use of the native plant species

The best adapted species to meet the environmental extremes of the area are those that have survived to the present. Emphasis is placed on using local ecotypes of dominant species having salinity tolerance, compatibility with domestic livestock and wildlife use, and aesthetically desirable features.

2. Transplanting of container-grown stock

The dominant species, usually shrubs and perennial grasses, could be grown from rooted cuttings, clones, or seedlings. Plants with a

root system of sufficient size to ensure survival would be transplanted at appropriate seasons of the year. Transplanting of bare-root and/or container-grown stock avoids the high probability of failure in seed germination and seedling establishment involved in direct seeding in arid regions.

3. Surface shaping

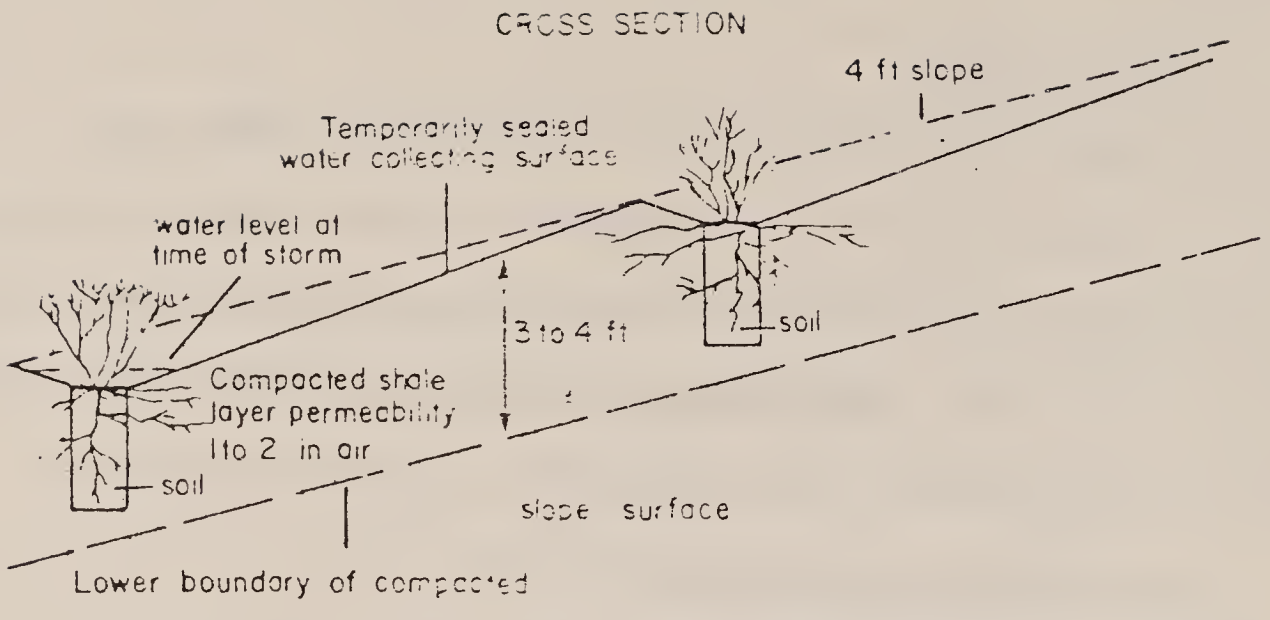
After compaction--to stabilize the pile and to reduce its permeability--the surface of the disposed shale pile would be shaped into terraces and slopes on side hills and into hillocks on the flat top (Figure 5-1). This shaping would provide a catchment slope for harvesting precipitation and a terrace for transplanting plants.

4. Soil surface stabilization

Mulches for binding surface particles, such as polyvinyl acetates should be applied to catchment slopes and terrace edges. The surface treatment would prevent movement of particles in the form of dust and assist or promote water harvesting.

5. Effective but limited use of topsoil

A trench about 19 x 30 inches (45 x 75 cm) would be filled with topsoil. The necessary growing medium to receive the container-grown native plants, the topsoil, would provide some inoculum of soil micro-organisms, a partial source of native plant seeds, and a buffer against high salt concentrations that might develop from the processed shale. Percolation of harvested water from the catchment slopes through the topsoil in the trench and out into the processed shale may suppress salinity levels around the root zone within the tolerance of the trans-planted native species. (However, we have not had sufficient processed shale or time to determine this.)



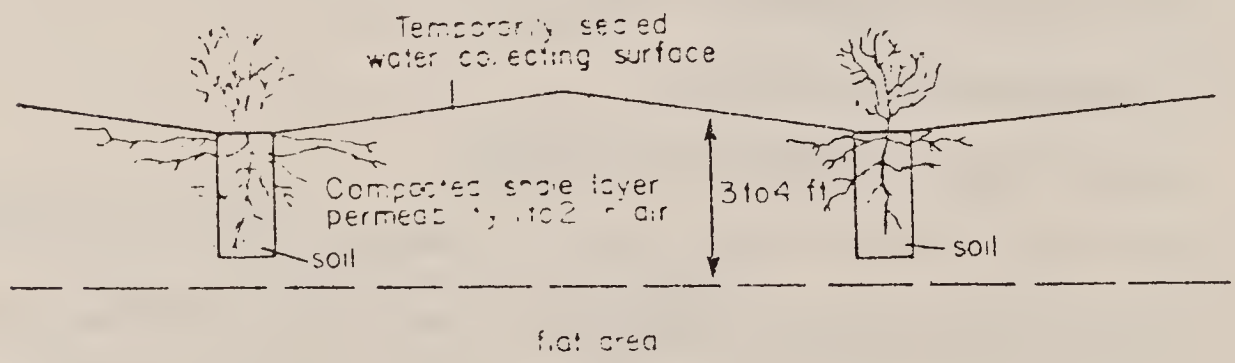


Figure 5-1 Surface modification and vegetation on processed shale slope area and flat area.

6. Fulfillment of minimal fertility requirements

Plants would be fertilized as needed and determined by existing and ongoing research. Some fertilization will be necessary as plant roots grow into the relatively infertile shale. (Because native plants of the region evolved in relatively low fertility soils, their fertility requirements are not as high as crop plants or some exotic species.)

7. Supplemental irrigation for plant survival and salinity management

As an added safeguard of plant survival during extended drought periods in the early years of the revegetation project, supplemental irrigation may be necessary. A drip-irrigation system, which would periodically supply low volumes of water through a flexible pipe system installed along each terrace (Hanks and Keller 1972); Bengson 1977), would be one way to supply the water, if required. This aspect of the proposed plan has not been determined because of a lack of processed shale in sufficient quantity to study the problem under field conditions. Several studies conducted provide some indication that salinity can be managed, however.

A brief summary of the research conducted under the direct sponsorship of the White River Shale Project or under other sponsorships available to the Institute for Land Rehabilitation is provided below. Theses of graduate students who worked on the research program and additional details can be found in the final report.

Summary of Research

1. Processed oil shale characteristics

To provide background information for growing plants on processed oil shale several studies investigated processed oil shale. Characteristics, processing methods and source of shale can have a great

influence on the nature of the shale residue. Generally, processed shale is black to grey in color, fine to gravely in texture, is biologically sterile and may crumble under pressure. The pH value ranges from 8 to 12 and the electrical conductivity of the saturation extract is usually in excess of 10 mmho/cm. The carbonate salt of Mg is of low solubility and is not leached. Sulfate salts of Na, Mg and Ca are abundant and $NaSO_4$ and $MgSO_4$ are readily leached but $CaSO_4$ is less so. Processed shale will break down physically under freezing/thawing and wetting/drying cycles. Such action chemically weathers the shale and reduces pH.

2. Plant tolerance to environmental extremes

Native plants are adapted to the severe environmental conditions of the oil shale tracts but their degree of adaptation to the salinity levels and ion concentrations that would occur in a processed oil shale pile are little known. An initial finding was that roots of native plants known to be salinity tolerant would grow in processed shale when water was not a limiting factor. Plant growth was enhanced when plants were planted in a topsoil plug surrounded by shale as compared with growth in straight shale. The same held true with a layer of soil over shale.

Fertilization with N and P appeared necessary for plant growth on processed shale according to results of several fertility studies. Fertilizer levels need not be high when native shrub species are used, however. Leaching plus fertilization of processed shale clearly enhanced plant growth. Two saltbush species responded to a higher degree to nitrate than urea or ammonium nitrogen fertilizer.

High salinity tolerance was exhibited by some native species grown on processed oil shale. Growth (yield) of each of four saltbush remained equal over a salinity range of EC_e 8 to 17 mmhos/cm. Even at EC_e values of 31 mmhos/cm the yields were about half as great as at an EC_e of 8.

Magnesium sulfate in high concentration appears to have a detrimental effect on saltbush growth. Leachate from shale was less inhibitory to plant growth than Na_2SO_4, $MgSO_4$ or NaCl over an EC_e range of 4.0 to 17.5 mmhos/cm.

Cuneate saltbush appeared to be more tolerant of salinity than fourwing saltbush, suggesting that a range of salinity tolerance exists among the group of salt tolerant native shrubs studies. Under conditions where salinity does not become concentrated excessively, several plant species are adapted for revegetation of processed shale.

Growth of the weedy annual cheatgrass was greater on leached processed shale or where soil was layered over shale than on processed shale. In contrast, Russian thistle seedlings grew on soil/shale treatments where an EC_e of 17 mmhos/cm was measured.

Endomycorrhizal fungi were found to be associated with greasewood, winterfat, fourwing saltbush, shadscale, needle-and-thread grass and Indian ricegrass.

3. Plant propagation, seedling growth, seed biology and collection of native plants

Propagation of native plants for revegetation may not be equally possible by the various methods such as seed germination, collection of wildings, or rooting of cuttings from stems or roots. Vegetative propagation offers an alternative when seed production fails, seed

germinate poorly or when wildings are not available. Methods of vegetative propagation where studied for numerous native shrubs of the region.

Big sagebrush rooted best when cuttings were taken near the end of the winter dormancy period, but the optimum rooting season for saltbush species was early summer. Big sagebrush stem cuttings required a high level of hormone (2.0% IBA) for root initiation while 0.3 to 0.8% IBA was adequate for rooting of saltbushes. Good rooting of saltbushes occurred without hormone during optimum season of collection. For best results cuttings should be taken from young woody stems and be at least 8 cm long. The range of plant variability in rooting response indicates that it may be possible to select for good rooting ability. Sex of plants was not an important factor in rooting shadscale or fourwing saltbush but may affect cuneate saltbush rooting. Cuttings from greenhouse grown greasewood plants rooted better than cuttings collected from plants in the field.

In a study of propagation containers for growing plants in the greenhouse, the size ranged from quart milk cartons to small cylinders with a 2.5 cm diameter and a depth of 16 cm. The best plant growth occurred in the largest containers. Field survival of seedlings and effective soil moisture uptake was greatest for seedlings grown in the larger size containers. Plants grown from seedlings had 10 percent greater survival and growth than those grown from cuttings.

Improved seed collection procedures and germination results for four species of saltbush that would be useful in rehabilitation are possible according to findings of studies conducted. Seed fill was

greatest in seeds at optimum maturity on the seed bearing stem. Seed size did not differ in relation to position on the stem. Seed size is important to seed fill -- the larger seeds of a given species were found to have the highest fill percentage. However, the thickest utricle wall (a deterrent to germination) was associated with the largest seeds. Germination percentage varied with seed size. Lowest germination was associated with medium and larger size seeds. Thus, emphasis should be placed on collecting well-filled seeds of medium to small size in the mid-season of seed maturity. Separation into size classes and scarification should increase germination percentages. Seeds of native shrubs, forbs, and grasses collected in the region of the oil shale tracts provided an inventory of seeds for research. Information on the kinds of species available and methods for their collection and cleaning can be useful in future rehabilitation activities.

4. Manipulation of field environment for improved plant growth

Several studies were conducted in the field to determine ways for improving soil moisture availability for plant growth on oil shale disposal piles or disturbed sites. Six soil surface stabilization materials were applied to plots on gentle slopes in a test for effectiveness in particle binding and surface strength. A polyvinyl acetate (PVA) material appeared to be the best choice. Water harvesting from some of the surface-stabilized slopes was observed 2 months after treatment.

Small basins, 75 cm in diameter and 10 cm deep, treated with a soil surface stabilizing material, polyvinyl acetate (PVA), were found to be effective in harvesting water and as a favorable means of increasing plant establishment under arid conditions. Basins treated at high rates of SBR harvested over twice the amount of precipitation or

simulated rainfall as non-treated basins. Plant growth in basins was 100 percent greater than on the flat surface.

A pilot model of a proposed method for rehabilitating a processed oil shale disposal pile was constructed. The model demonstrated the concept and feasibility of creating water harvesting slopes, treatment of slopes with a soil stabilizing material, making a trench in a flat area at the base of the slopes and filling it with topsoil, and planting native plants in the topsoil-filled trench. Of the two types of processed shale (Paraho and Union Oil Co. processes) used to fill the pilot model, the coarse-textured Paraho shale had a considerably greater through-percolation than the finer textured Union Oil Co. processed shale. Surface stabilization of slopes provided for harvesting of water onto the topsoil-filled terrace. Plant growth was the most favorable in the section of the trench below the surface-stabilized, finer-textured shale. The EC_e, pH, TDS, and various ions in the leachate were analyzed and compared with culinary water from the Vernal City water supply.

Water harvesting slopes were created on a compacted oil shale disposal pile at Anvil Points, Colorado. Simulated rainfall application of 2.34 cm over a 10 minute period resulted in considerable runoff from all but mulch-treated plots. The EC_e of runoff was highest during the first one-fourth of accumulated runoff and gradually reduced. Runoff from surfaces treated with paraffin did not increase in salinity but remained below 2.5 mmhos/cm over the 10 minute period.

Control of plant competition can increase plant survival and growth on disturbed sites or other locations where the density of annual weeds may limit rehabilitation success. Clean cultivation during the first

year after planting 4 species of container-grown plants resulted in 63 percent survival as compared with 45 on non-weeded plots. Control of competition for 2 years resulted in 91 percent survival.

5. Field establishment and planting methods

Sites disturbed by geologic core drilling presented a challenge early in the conduct of the research program because of their harsh environmental conditions, exposure of subsurface soil, loss of vegetation and subsequent animal use. From a first-year survival percentage of 66 the bare root plantings of nine native species were reduced to 21 percent at the end of 1978. Low precipitation, plant competition and rodent damage were principal causes of losses. In contrast, container-grown plantings of fourwing saltbush showed a 75 percent survival after four years. Irrigation and fertilization at planting time provided no significant benefits.

A major field study compared planting treatments: fall and spring planting of seeds, bare root, and container-grown transplants of nine shrubs and five grass species in three diverse locations. Direct seeding was unsuccessful but container-grown plants survived 60 percent after four years which was 11 percent better than bare root transplants. Planting in spring was superior to fall planting under the conditions of the area studied. Addition of water plus fertilizer at planting time did not give a consistent increase in establishment success at all sites. The most successful shrub species planted were fourwing saltbush, greasewood, winterfat and black sagebrush. The most successful grasses were western wheatgrass and crested wheatgrass.

Antidessicant chemicals applied to shrub transplants at planting time did not increase survival.

Root and top pruning of bare root transplants did not increase plant survival. However, the practice is expected to be useful on medium to large-sized plants.

5.2.2 Research Plans for 1979

Some work seeking to confirm several findings discussed in the final report will continue in 1979 but no additional extensive work is envisioned until production of shale oil begins on Ua/Ub.